

Island Grouper (*Mycteroperca fusca*)

Status Review Report



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Executive Summary

On July 15, 2013, NMFS received a petition to list 81 species of marine organisms as endangered or threatened species under the Endangered Species Act (ESA). If an ESA petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). NMFS determined that for 27 of the 81 species, including the island grouper (*Mycteroperca fusca*), the petition had sufficient merit for consideration and that a status review was warranted (79 FR 10104, February 24, 2014). This document is the ESA status review report for the island grouper.

The island grouper is a subtropical, demersal species that is endemic to volcanic archipelagos of Macaronesia: Canary (Spain), Madeira and Azores (Portugal), and Cape Verde. This species is characterized as having both a “restricted” geographic range (i.e., less than 800,000 km²) and a “narrow” depth range (i.e., < 30 m). The island grouper is found predominantly near rocky or sandy-rocky sea-beds. Studies have shown a positive correlation between island grouper abundance and structural complexity, algal cover, and upright seaweed cover. The island grouper is a slow-growing, long-lived species which can attain maximum sizes of at least 86 cm total length and 7.8 kg. While slow growth after the first few years is typical for the genus, the island grouper is particularly slow-growing ($k = 0.062$ per year) when compared to other *Mycteroperca*. Longevity of island grouper is estimated to be between 30 and 40 years. The island grouper is a nektobenthic (i.e., free-swimming, bottom oriented) macrocarnivore that preys on fish, crustaceans, and cephalopods. Island grouper are protogynous hermaphrodites – large females undergo sexual transitions to become males.

The following demographic risk factors were considered in the extinction risk analysis: abundance; growth rate/productivity; spatial structure/connectivity; and diversity. These demographic risk factors reflect concepts that are well founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. According to Section 4 of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any (or a combination) of the following factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Specific threats to the island grouper from each of these five factors were considered.

Due to the lack of information regarding threats and the species’ life history and ecology, significant uncertainties exist surrounding the levels of risk posed by these demographic factors and threats. Scientific and commercial information available for this analysis was limited, both temporally and spatially. Because information on island grouper threats and demographic risk factors is sparse and often non-quantitative, a 3-item qualitative scale was used for assessment of overall extinction risk:

- Low risk - it is unlikely that this species is at risk of extinction due to trends in abundance, productivity, spatial structure or diversity.
- Moderate risk - the species exhibits a trajectory indicating that it is approaching a level of abundance, productivity, spatial structure, and/or diversity that places its persistence in question.

- High risk - the species is at or near a level of abundance, productivity, spatial structure, and or/diversity that places its persistence in question.

Data from Underwater Visual Census studies and fisheries landings indicate that the island grouper is rare throughout much of its limited range, and very rare in some areas subjected to heavy fishing pressure. Although there are no population abundance estimates available for island grouper, low and decreased density combined with a highly restricted range indicate that small population size is likely a risk factor for this species. Demographic viability factors related to growth rate and productivity are also likely to contribute to the extinction risk based on the following island grouper life history characteristics: slow growth, late maturation, low population turnover rate, large size, and long life span. Although information on spatial structure, connectivity, and dispersal characteristics specific to island grouper is sparse, it is somewhat likely that these factors represent a demographic viability risk to this species. Typical of archipelago ecosystems, the Macaronesian Islands are highly fragmented, as geographic distances, bathymetry, and other physical factors result in various degrees of isolation between local populations of demersal fish species. Island grouper are rare in many areas studied, and the few documented areas with relatively higher abundance are small and patchily distributed throughout the species' range. The available information suggests that this species is inherently susceptible to fragmentation which could result from further population declines. Because there is insufficient information on genetic diversity, this demographic viability criterion presents an unknown likelihood of contributing to the island grouper's extinction risk.

The island grouper's intrinsic vulnerability to fishing is very high. Demographic viability risk factors related to the island grouper's growth rate, productivity, spatial structure, and range size all contribute to this species' vulnerability to fishing overexploitation. As a protogynous hermaphrodite, the island grouper may be even more susceptible to fishing which, through selective removal of males, could reduce reproductive capacity. Certain behavioral traits (i.e., territoriality, site specificity, and spawning aggregations), which are common among groupers, often result in grouper species being an easy target for fishermen. Although not well-studied in the island grouper, these traits may also add to the fishing vulnerability of this species.

Historical fisheries data are not available to evaluate long-term trends in island grouper landings, directed effort, or catch rates over time. The limited commercial and artisanal catch data available indicate that, in recent years, island grouper landings have been relatively small, and this species is currently a very minor component of commercial and artisanal fisheries throughout its range. The small contribution to recent fisheries landings is consistent with abundance information suggesting the island grouper is generally a rare species.

Several studies have shown a negative correlation between island grouper abundance and level of fishing pressure. These results suggest that fisheries overexploitation has negatively impacted island grouper abundance, and some heavily fished areas in the Canary Islands have likely experienced a sharp decline. Based on the cumulative information available, I conclude that there is a reasonable likelihood that artisanal fishing overutilization contributes to the island grouper's risk of extinction in a significant way (i.e., in a sufficiently great or important way as to be worthy of attention). There are also indications that rapidly expanding recreational fisheries contribute significantly to the overutilization of island grouper in some parts of the species' range.

Current fishing regulations designed to limit catch and effort are inadequate for addressing the direct threat to island grouper from fishing overutilization. In general, there are few restrictions placed on demersal fisheries throughout the island grouper's range. In areas where regulations (e.g., size limits and gear restrictions) do exist, their effectiveness is likely reduced by lack of enforcement and relatively high levels of non-compliance. A few no-take marine reserves have been established within the island grouper's range. However, given their small size, physical isolation from one another, and insufficient enforcement, the currently established no-take reserves are likely inadequate to protect island grouper from the future threat of fishing overutilization. Therefore, I conclude that there is a reasonable likelihood that the lack of adequate regulatory mechanisms and enforcement represent threats to the island grouper that contribute significantly to this species' extinction risk.

Due to the species' preferred depth range, and the surrounding volcanic island bathymetry, island grouper habitat is typically confined to a narrow band within a few kilometers from shore. Close proximity to shore increases the risk of habitat modification from human activities within the coastal zone, particularly on some of the more densely populated islands within the Macaronesian Region. Potential threats to island grouper habitat include: declines in benthic cover (i.e., seaweeds and macroalgae) due to overfishing of key sea urchin predators; physical alteration and armoring of the coast; destructive fishing practices; pollution; and the effects of global climate change. While these ecosystem disturbances are well documented, studies linking habitat related threats to declines in island grouper abundance are lacking. Although the cumulative impact of anthropogenic threats has likely modified some portion of the island grouper's habitat, there is not enough scientific information available to support a conclusion that habitat associated changes contribute to the extinction risk of this species in a significant way. The introduction of invasive species from aquaculture escape events and ship ballast water also poses a potential threat to island grouper through increased competition for limited resources (e.g., food, shelter) and the possible spread of diseases and parasites. However, as with habitat related threats, there is not enough scientific information available to support a conclusion that threats related to competition, disease or predation contribute to the island grouper's extinction risk in a significant way.

In summary, the island grouper exhibits demographic risk factors related to abundance, growth rate and productivity, and spatial structure and connectivity. The cumulative magnitude of these risk factors is likely approaching a level of vulnerability that places the species' persistence in question. In addition, there is a reasonable likelihood that the operative threats of fishing overutilization and the lack of adequate regulatory mechanisms contribute significantly to the island grouper's risk of extinction. After considering the cumulative evidence from all the information available, **I conclude that the island grouper faces a moderate risk of extinction throughout its range.**

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Background

On July 15, 2013, NMFS received a petition from WildEarth Guardians to list 81 marine species or subpopulations as endangered or threatened species under the Endangered Species Act (ESA). The island grouper was one of the species included in this petition. Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). This document is the ESA status review report for the island grouper, *Mycteroperca fusca*.

The ESA requires that listing determinations be made on the basis of the best scientific and commercial information available, after taking into consideration any efforts by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect the species (16 U.S.C. §1533(b)). After compiling the best available information through April 6, 2015, I completed a thorough review of the biology, population status and future outlook for the island grouper. This document reports the findings of the scientific review as well as the conclusions regarding the extinction risk of the island grouper as a candidate for listing under the ESA. These conclusions are subject to revision should important new information arise in the future.

Island Grouper Life History and Ecology

Taxonomy and Distinctive Characteristics

Phylum: Chordata
Class: Actinopterygii
Order: Perciformes
Family: Serranidae
Sub-family: Epinephelinae
Genus: *Mycteroperca*
Species: *fusca*

The island grouper (*Mycteroperca fusca*) is one of 15 species within the genus *Mycteroperca*: 5 species are distributed in the Pacific Ocean, and 10 species (including the island grouper) are distributed in the Atlantic Ocean. Diagnostic features of the island grouper include the following: oblong and compressed body with depth less than head length; preopercle serrae enlarged at angle forming a rounded lobe below a shallow indentation on vertical limb of the preopercle; lower jaw extends well in front of upper jaw; 11-14 gill rakers on upper limb, 20-24 on lower limb, total 32-36; dorsal fin with 11 spines and 14-16 rays; anal fin with 3 spines and 10-12 rays, the fin margin rounded; pectoral-fin rays 15-17; and caudal-fin rear margin truncate (juveniles) to concave (adults) (Heemstra and Randall, 1993).

The island grouper was first described under the name *Serranus fuscus* by Lowe (1836) based on specimens from Madeira, Portugal. For many years *M. fusca* were confused with another closely related species, *M. rubra*. Based primarily on differences in gill raker counts, Heemstra (1991) established that the species found in the Atlantic Macaronesian region (from the Azores to Cape Verde) was *M. fusca* (with 20-24 lower limb gill rakers), with the distribution of *M. rubra* (with

28-31 lower limb gill rakers) being limited to the west coast of Africa and Mediterranean Sea (Heemstra and Randall, 1993). Reports of the grouper species *Epinephelus alexandrinus* from Madeira were also likely misidentified *M. fusca* (Heemstra, 1991). *Serranus simonyi* described by Steindachner (1891) based on two specimens collected from the Canary Islands is also regarded as a synonym of *M. fusca* (Heemstra, 1991). Other common and local names for *Mycteroperca fusca* include comb grouper, badejo (Azores and Madeira, Portugal; Cape Verde), abade, abae, sama (Canary Islands, Spain), and mottled grouper (Cape Verde) (Heemstra and Randall, 1993; Medina et al., 2007). For this report I use the common name island grouper.

Island grouper display up to eight different color patterns (Bustos, 2008). Adults are brownish or dark grey, with irregular pale blotches and spots and a prominent maxillary streak. Under stress this pattern may be reversed so that the head and body are pale with irregular dark markings. Juveniles are mottled greenish-brown with prominent white spots on head and body, white streaks on median fins, with hyaline golden pectoral fins (Craig et al., 2011). The color pattern of mature females from the Canary Islands suggests sexual dichromatism (i.e., males and females differ in color) (Bustos, 2008). A large proportion of sexually active females have yellow pigmentation (dorsal fins and/or chest, ventral or uniformly throughout); males are uniformly brown and did not display dichromatism (Bustos, 2008). A few uniformly golden island grouper have been reported from Madeira, and this species is also known to display a yellow (xanthic) color phase (Heemstra and Randall, 1993; Wirtz, 2007). After death the island grouper color is a very nondescript uniform grey or brown (Craig et al., 2011).

Range, Distribution, and Habitat Use

The island grouper is a subtropical species (40° N - 10° N) that is endemic to volcanic archipelagos of Macaronesia: Canary (Spain), Madeira and Azores (Portugal), and Cape Verde (Figure 1) (Heemstra and Randall, 1993). There are no confirmed reports of island grouper off the coast of West Africa, although few ichthyofauna studies have been conducted in this region. One specimen was caught by a spearfisherman off Israel's coast (Heemstra et al., 2010), but there are no data confirming the existence of an island grouper population in the Mediterranean. Possible explanations for this fish's arrival at the eastern margin of the Mediterranean include transport through the Strait of Gibraltar along the North African coast in a ship's ballast water, or escape from a mariculture farm.

The Macaronesian islands are all volcanic in origin but differ significantly in terms of size, habitat types, fish species diversity, and human population density. The Canary Islands are located between 27° and 29° N latitude and 13° and 18° W longitude at a minimum distance of 100 km and maximum distance of 450 km off the coast of Morocco (Bustos, 2008). The Canary Islands archipelago is formed by seven main islands with 1,379 km of coastline, a total land area of 7,447 km², and a human population size of approximately 2.1 million (Popescu and Ortega-Gras, 2013). The Madeira archipelago is located from 32° 37' to 32° 52' N latitude and 16° 39' to 17° 15' W longitude, 754 km from the coast of Africa and 964 km southwest of Lisbon (Ribeiro, 2008). The archipelago consists of the two main inhabited islands (Madeira and Porto Santo) with an estimated combined human population of 268,000, and five uninhabited islands (Desertas and Selvagens islands). The Madeira archipelago has 153 km of mostly rocky and steep coastline, and a total land area of 801 km². The Azores archipelago is located between 37° and 40° N latitude and 24° and 32° W longitude, about 1,500 km west of Lisbon and

1,900 km southeast of Newfoundland. It is composed of nine islands and some small islets (Harmelin-Vivien et al., 2001) with 667 km of coastline, a total land area of 2,333 km², and a human population size of approximately 246,000. The Cape Verde archipelago is located between 14° and 17° N latitude and 22° and 25° W longitude, due west of Senegal off the west coast of Africa. It is composed of ten islands (of which nine are inhabited) and eight islets, with 1,020 km of coastline, a total land area of 4,033 km², and a human population size of approximately 531,000.

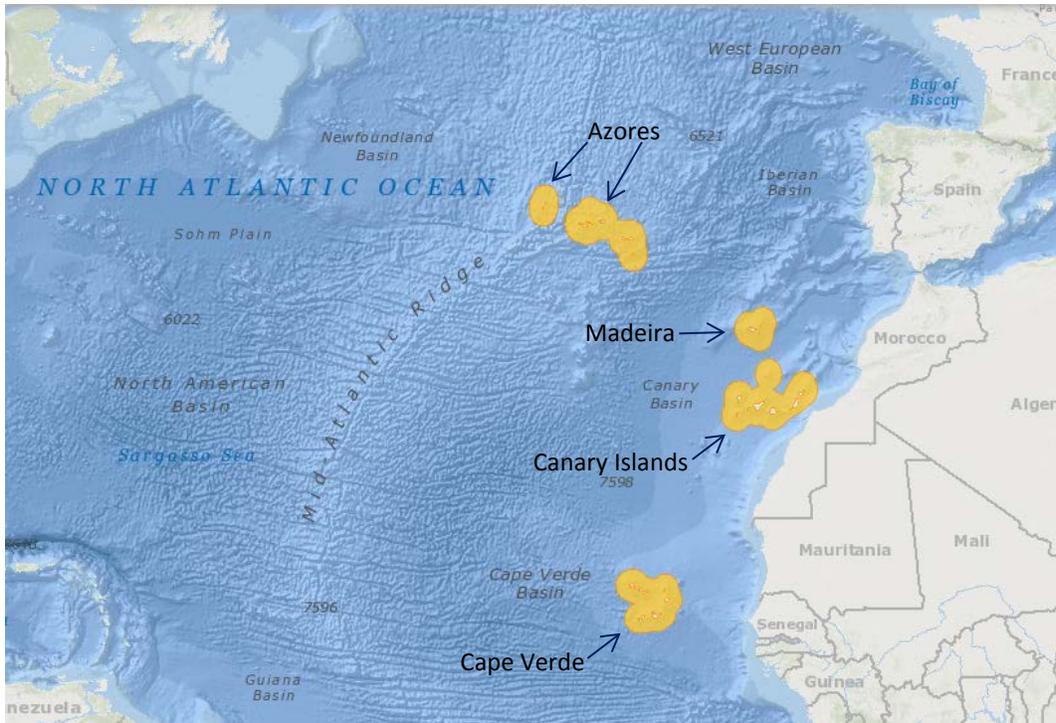


Figure 1. Range map of island grouper (*Mycteroperca fusca*) showing four main archipelagos (from Rocha et al., 2008).

Based on mapping of known areas of occurrence, Morris et al. (2000) characterized the range size of 85 groupers as either “widespread,” “limited,” or “restricted”. The island grouper was one of out of 12 grouper species characterized as having a “restricted range” (defined as less than 800,000 km²), the smallest range category. The seafloor bathymetry around the Macaronesian islands is typically abrupt with a narrow contiguous shelf and a steep slope plunging to depths of more than 1,000 meters. As a result, viable habitat for species living within the upper 50 m (including island grouper) is smaller than on continental shores, limiting the abundance of demersal fishes (Diogo and Pereira, 2013a; Popescu and Ortega-Gras, 2013). Island grouper have also been observed in the upper portion (18-30 m depths) of offshore seamounts rising up from the ocean floor (Monteiro et al., 2008) and on offshore artificial reefs (Herrera et al., 2002).

Based on a wide range of sources, Morris et al. (2000) classified the island grouper as having a “narrow depth range” defined as occurrence at depths typically less than 20-30 m. Although

island grouper have occasionally been reported at greater depths (e.g., 50 m by Heemstra and Randall, 1993; 150 m by Bustos, 2008; and 200 m by Craig et al., 2011), based on the majority of observations, it is assumed that their normal distribution in the water column is at depths less than 30 m. Most data on the spatial distribution of island grouper are from underwater visual census (UVC) studies using SCUBA gear, which limits the range of depths surveyed. There is thus little information regarding the presence or relative abundance of island grouper at depths greater than 30 m. In a UVC study of the abundance and spatial distribution of fish species on five islands in the Azores archipelago, island grouper were found within three shallow depth ranges sampled (0-10 m; 11-17 m; and 18-25 m) but were not observed by divers in the 30-42 m depth range (Harmelin-Vivien et al., 2001). Monteiro et al. (2008) studied fish assemblages from the upper parts of two seamounts (João Valente Bank and Northwest Bank) in the Cape Verde archipelago. Island grouper were seen from 18-30 m depths on 64.3% of dives at the algae covered João Valente Bank, but were not observed at the Northwest Bank which only rises to a depth of 35 m with virtually no algae cover. Gonzalez et al. (2014) conducted six exploratory fish-trapping surveys between 2003 and 2012 off the Cape Verde islands of Boa Vista, Santiago, São Vicente, Santa Luzia, Sal, and São Nicolau, at depths ranging from 66 m to 1060 m. No island grouper were collected during any of these surveys. UVC studies also suggest that island grouper rarely occupy very shallow zones from the shoreline to 5 m (Ribeiro, 2008; Sangil et al., 2013b; Vidal-López, 2014; Toledo-Guedes et al., 2014).

Like most groupers, the island grouper is a demersal species that occurs near the bottom, predominantly in rocky areas (Heemstra and Randall, 1993). In the Canary Islands, island grouper are found on rocky and sandy-rocky sea-beds, most often in dips and bays where it swims around large rocks (Bustos, 2009). Bustos (2008) found island grouper abundance was positively correlated with structural complexity within La Graciosa Marine Reserve (Chinijo islands), and with algal cover (*Hypnaea spinella*) around El Hierro island. Sangil et al. (2013b) found a highly significant positive correlation between island grouper biomass and upright seaweed cover around La Palma island (Canary Islands).

All groupers pass through a pelagic larval phase, lasting between 20-50 days, during which they can actively swim (Aburto-Oropeza et al., 2008). After the larval phase, groupers acquire juvenile characteristics during which they settle into shallow, coastal nursery habitats (e.g., *Sargassum* beds, seagrass areas, mangroves, and estuaries); this nursery stage can last up to two years. La Mesa et al. (2002) found that juvenile dusky grouper (*Epinephelus marginatus*) showed a preference for sheltered microhabitat (i.e., cavities and recesses) and avoided visually exposed locations (convex substrates and very large visual fields). Although the preferred nursery habitat of island grouper has not been studied, juveniles have been found in tide pools (Heemstra and Randall, 1993) and like dusky grouper may avoid exposed locations.

Growth and Reproduction

The island grouper is a slow-growing, long-lived species which can attain maximum sizes of at least 86 cm total length (TL) and 7.8 kg (Bustos, 2008; Bustos et al., 2010). Longevity of island grouper in the Canary Islands was calculated by Bustos (2008) to be around 30 years. Based on maximum sizes reported from historical records in the Canary Islands, and the estimated island grouper length at age relationship (Figure 2), maximum age for this species may be closer to 40

years (Bustos et al., 2009). The instantaneous rate of natural mortality estimated for island grouper is between 0.146 and 0.158 per year (Bustos, 2008).

Studies of island grouper age and growth (Bustos et al., 2009) and reproductive biology (Bustos et al., 2010) were based on fish collected from commercial catches off Gran Canaria and Fuerteventura (Canary Islands) between January 2004 and December 2005. Length at age was described by the von Bertalanffy growth model with the following parameters: $L_{\infty} = 898$ mm; $k = 0.062$ per year; and $t_0 = -3.83$ years. Two to nine year-old fish were the dominant age classes, with only 22% of fish being ten years old or older. The oldest fish in this study was around 20 years old, 50% less than the maximum age estimated by Bustos (2008). Age 0 and 1 specimens were unavailable in this study as they are too small to recruit to the fishery. On average, over 28% of island grouper growth was achieved by the second year; by the fourth year this species attains lengths of approximately half of the maximum length observed. In general, growth within the genus *Mycteroperca* tends to be faster in the early stages of life, slowing down considerably in later stages (Bullock and Murphy, 1994; Manickchand-Heileman and Phillip, 2000; Strelcheck et al., 2003). Consequently, the von Bertalanffy model typically does not describe the growth of *Mycteroperca spp.* properly for the first few years of life, as evidenced by relatively large negative t_0 values.

While slow growth after the first few years is typical for *Mycteroperca*, the island grouper is particularly slow-growing (0.062 years^{-1}) when compared to closely related species (Figure 3): *M. bonaci* 0.16 years^{-1} (Manooch, 1987); *M. olfax* 0.181 years^{-1} (Rodríguez, 1984); *M. microlepis* $0.12\text{-}0.16 \text{ years}^{-1}$ (Manooch and Haimovici, 1978; Manooch, 1987; Hood and Schlieder, 1992); *M. phenax* 0.091 years^{-1} (Manooch, 1987; Matheson et al., 1986); *M. tigris* 0.11 years^{-1} (García-Arteaga et al., 1999); *M. rubra* 0.106 years^{-1} (Paiva et al., 2004); and *M. rosacea* 0.092 years^{-1} (Díaz-Uribe et al., 2001) (All sources cited in Bustos et al., 2009). The growth rate estimated for island grouper by Bustos et al. (2009) is very similar to the growth rate estimated for *M. interstitialis* (0.057 years^{-1}) in Trinidad and Tobago (Manickchand-Heileman and Phillip, 2000).

Significant differences were found between males ($n = 35$) and females ($n = 153$) for mean age (males 10.31 years versus females 7.07 years), L_{∞} (males 952 mm versus females 888 mm), and growth rate k (males 0.053 per year versus females 0.063 per year) (Bustos, 2008). In this study, female weights ranged from 158 to 5,509 g (total weight) and male weights ranged from 452 to 5,469 g. The parameters of the ratio of total length to total weight were $A = 0.00000798$, $b = 3.082$ for females, and $A = 0.00000710$, $b = 3.079$ for males.

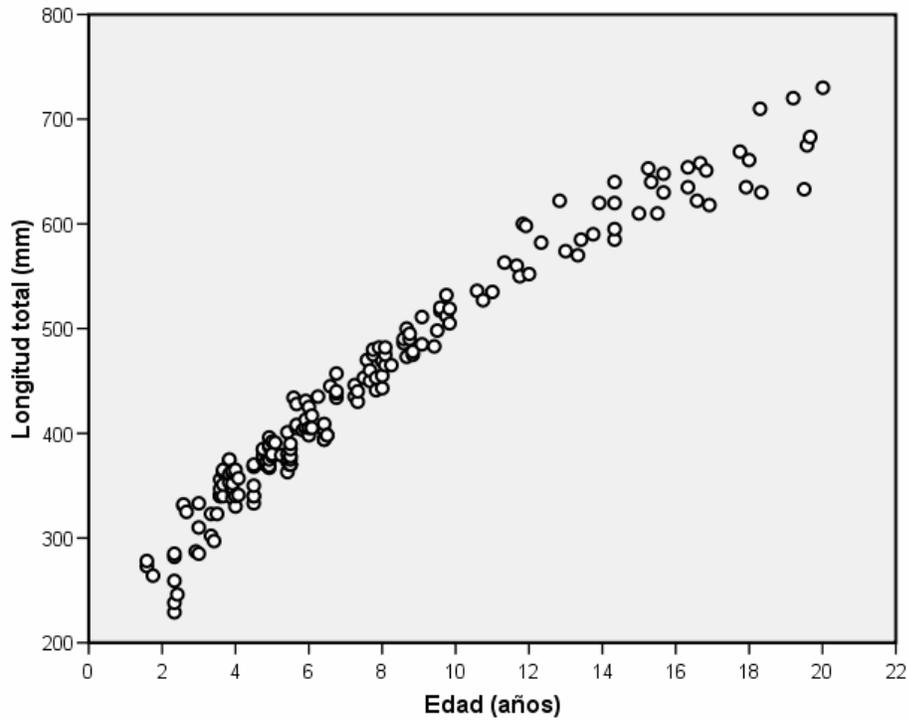


Figure 2. Relationship of age to total length predicted from von Bertalanffy growth model for island grouper (n=188) off the Canary Islands (from Bustos, 2008).

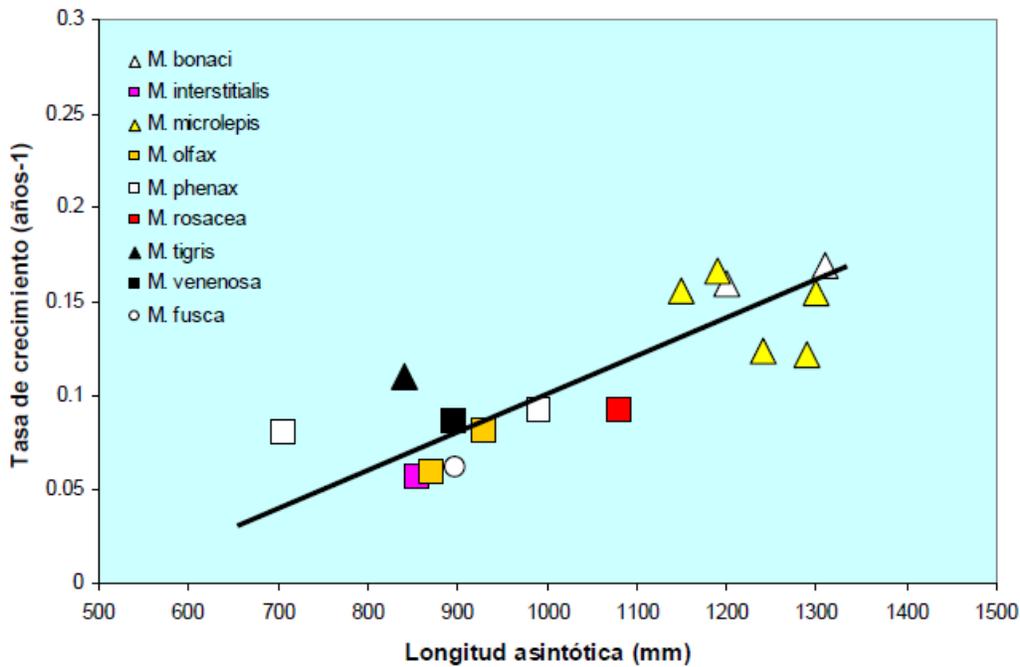


Figure 3. Growth rate (y-axis) versus asymptotic length (mm TL, x-axis) for species of the genus *Mycteroperca* from various sources in the literature. Island grouper growth rate represented by white circle (from Bustos, 2008).

Bustos et al. (2010) studied the pattern of sexual development and reproductive characteristics of island grouper in the Canary Islands. Results of histological analyses and demographic structure suggest a monandric protogynous sexual pattern in island grouper, where males develop only through sex change. The smallest males in the sampled population were 428 mm TL or about 7 years of age, which are above the size (398 mm) and age (5-6 years) of 95% female maturity (Bustos et al., 2009). Island grouper sexual transition took place between 428-725 mm TL, with 50% of females transformed into males at 678 mm TL. The presence of females in the larger size categories implies that the conversion (female to male) is not essential in all individuals. This is also consistent with the broad range of sizes at which sexual reversal is found, and the relatively large size at which 50% of the females reversed to males. Males were only observed in the larger size categories (Figure 4), with a significant difference in mean TL between mature females (470 mm) and males (559 mm). The overall sex ratio of males to females (1:4.9) and the sex ratio of males to mature females (1:3.4) were both significantly different from 1:1.

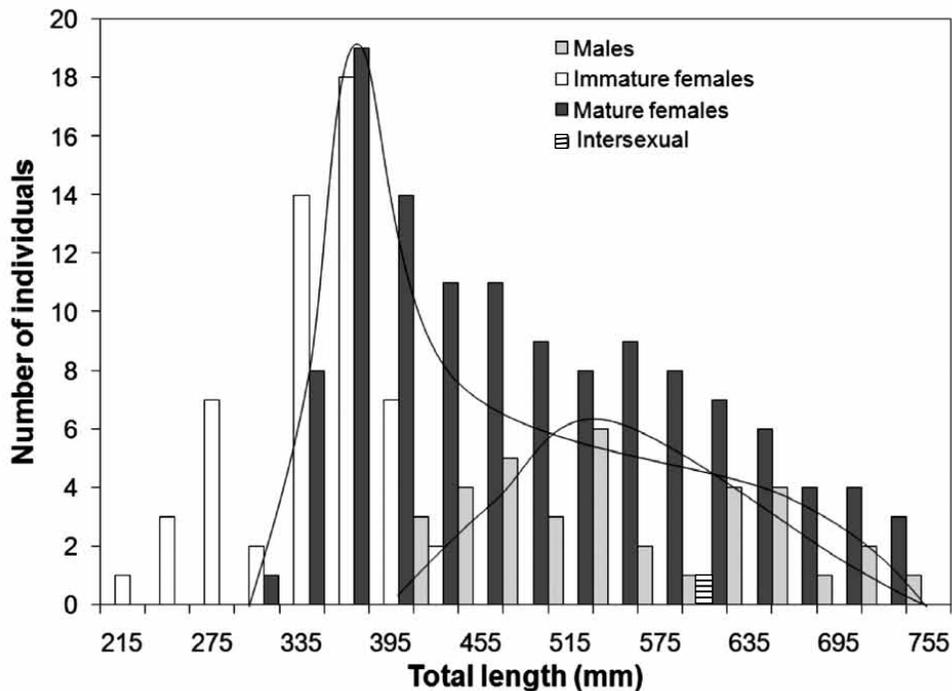


Figure 4. Size-frequency distribution of island grouper by sex and maturity stage from Canary Islands commercial fishery landings from January 2004 through December 2005. Intersexual refers to fish in the process of transitioning from female to male. (from Bustos, 2010).

Bustos et al. (2010) found that island grouper in the Canary Islands reach sexual maturity at approximately 50% of the maximum observed size. The length at which 50% of the population reaches sexual maturity was estimated at 335 mm TL, or about 4 years old. Of the females over 398 mm TL (5-6 years old), 95% were considered to be mature. The smallest-sized mature female was 310 mm TL and the largest mature female (Tmax) was 725 mm TL. Studies on other *Mycteroperca* species have shown a significant positive correlation between female fecundity and total length, body weight, and age (Collins et al., 1998; Aburto-Oropeza et al., 2008).

In the Canary Islands, reproduction is initiated in February, when water temperatures are around 18° C, and continues through August or September when temperatures peak around 24-26° C (Bustos et al., 2010). The central period of spawning, as defined by months when 50% or more of females are in vitellogenesis (i.e., yolk deposition), is from April to July (Bustos et al., 2010). A prolonged spawning period suggests the existence of favorable environmental conditions for spawning and development of larvae.

The formation of spawning aggregations is a common trait among groupers. Based on a combination of semi-structured interviews and published literature, Sadovy de Mitcheson et al. (2008) found evidence of spawning aggregations in 8 *Mycteroperca* spp. Although I could not find any published studies on island grouper reproductive behavior, spawning aggregations have been reported through personal communication (J.P. Barreiros, UAC/IMAR cited in Rocha et al., 2008) from two locations in the Azores. Sadovy de Mitcheson et al. (2012) also note that the island grouper is a species that is known to form spawning aggregations, although no specific citation was provided.

Sadovy de Mitcheson et al. (2008) described two types of spawning aggregations among grouper species: 1) resident aggregations - individuals make short journeys (a few hours or less) from residence sites to the aggregation site where spawning may occur many times a year, and 2) transient aggregations - individuals migrate long distances over several days (or weeks) to the aggregation site during a very specific portion of the year. The prolonged spawning period for island grouper in the Canary Islands, as described by Bustos (2008), may be more indicative of resident aggregations.

Feeding and Trophic Role

The island grouper is classified as a nektobenthic (free-swimming, bottom oriented) macrocarnivore that preys mostly on large crustaceans, cephalopods and fishes (Harmelin-Vivien et al., 2001). Bustos (2008) analyzed stomach contents of island grouper (n = 46) collected from El Hierro (Canary Islands archipelago) between January and September 2004. Of those stomachs with undigested or partially digested prey, she found 86% contained finfish remains (scales, spines or vertebrae), 27% contained fishing bait (mackerel heads), 9% contained cephalopods, and one stomach contained an Azore chromis (*Chromis limbata*). Based on UVC surveys in the Canary Islands, island grouper abundance has been positively correlated with the following confirmed prey species from stomach content analysis: Azore chromis - *Chromis limbata*; ornate wrasse - *Thalassoma pavo*; Bogue - *Boops boops*; and Canary damsel - *Abudefduf luridus* (Bustos, 2008).

Island grouper abundance, from UVC surveys conducted around El Hierro island, was also positively correlated with abundance of three moray eel species (*Gymnothorax miliaris*, *Muraena helena*, and *Gymnothorax unicolor*) (Bustos, 2008). Although moray eels have diet and habitat preferences (i.e., cavities in rocks) similar to island grouper, feeding strategies differ significantly: moray eels are sedentary ambush predators, whereas island grouper are mobile hunters that actively explore their territories for prey (Bustos, 2008).

Barreiros and Santos (1998) studied the feeding habits and predatory behavior of the dusky grouper (*E. marginatus*) in the Azores. Dominant prey species found were octopus (*Octopus vulgaris*), slipper lobster (*Scyllarus arctus*), emerald wrasse (*Centrolabrus trutta*), and redlip blenny (*Ophioblennius atlanticus*). Fish constituted the main prey for medium sized dusky grouper (under 90 cm TL), although octopus and crustaceans were also important prey items. For large dusky grouper (over 90 cm), octopus were the dominant prey item. Given the similarities in size, habitat, and trophic level between the two species, it is likely that island grouper and dusky grouper diets overlap to some extent. However, the apparent switch from a diet of predominantly fish to one of predominantly octopus that occurs in dusky grouper around 90 cm is less likely for island grouper, which generally do not get this large.

Abundance and Population Structure

There are no historical or current abundance estimates for island grouper. Island grouper mean densities and relative abundances have been reported by several researchers at various sampling locations throughout its range. These studies are described below for each of the four main archipelagos in the Macaronesian region.

Azores

Harmelin-Vivien et al. (2001) studied the abundance and spatial distribution of fish species on five islands (São Miguel, Faial, Pico, São Jorge, and Graciosa) in the Azores archipelago (Figure 5). UVC surveys were conducted in 1979 using a circular point count method with mean area sampled from 350-450 m² during 10-15 minute observation periods. A total of 27 censuses were distributed across three depth ranges (0-10 m; 11-17 m; 18-25 m). Mean density and percent occurrence for island grouper by depth range were as follows: 0-10 m, 0.06 fish/100 m², present in 22% of censuses; 11-17 m, 0.03 fish/100 m², present in 10% of censuses; 18-25 m, 0.06 fish/100 m², present in 25% of censuses. The dusky grouper (*E. marginatus*), was also rarely observed in this study from 0-17 m, but was relatively more common in the 18-25 m depth range: 0.47 fish/100 m², 88% occurrence.

Bertoncini et al. (2010) studied the community structure of shallow rocky reef fish fauna around the islands of Terceira and Corvo from June to October of 2007. UVC surveys were conducted at eight sampling locations and four depth strata (2, 6, 9, and 14 m) using a line transect technique (20 m x 2 m) with divers swimming the length of the transect twice to account for more cryptic species missed in the initial pass. Island grouper were extremely rare within these fish communities: < 1% frequency of occurrence in samples; relative abundance 0.01%; and mean density < 0.10 fish/100 m². By comparison, dusky grouper were found in 28.4% of transects sampled with a mean density of 1.8 fish/100 m².

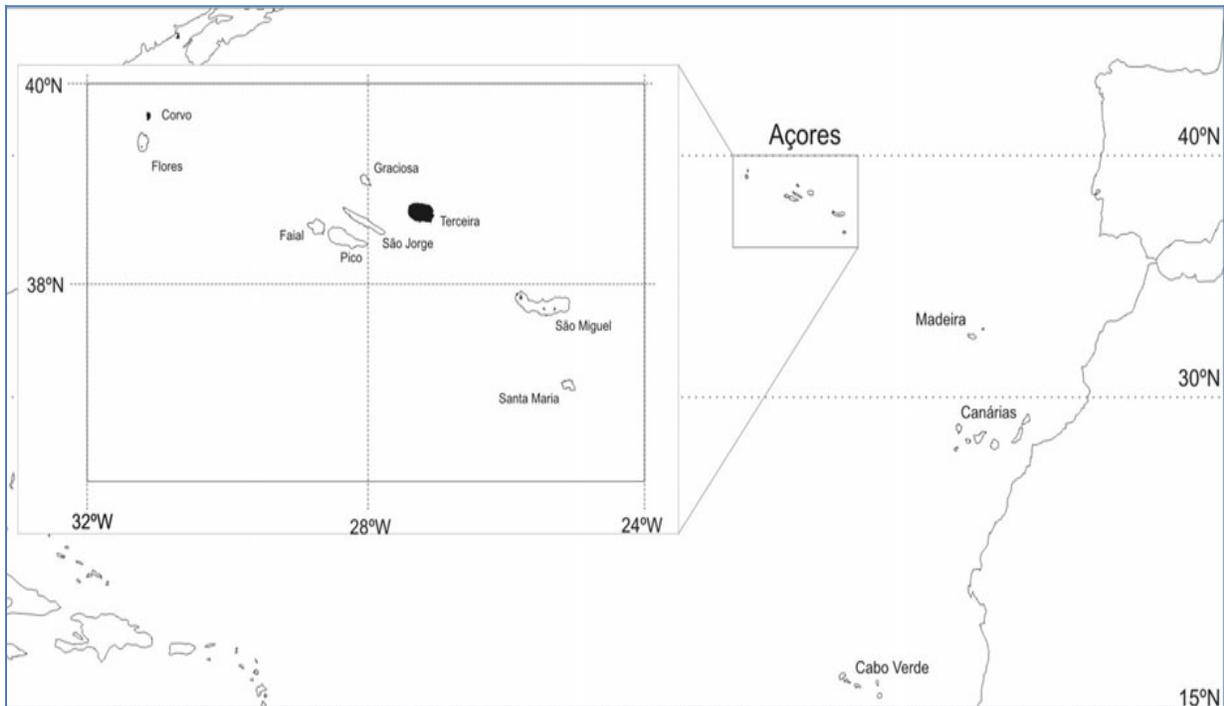


Figure 5. Location of the nine main islands within the Azores archipelago (from Bertocini et al., 2010).

Madeira

Ribeiro et al. (2005) studied fish assemblages in Cais do Carvao Bay off Funchal (Madeira Island) from November 1997 through August 1998 (Figure 6). UVC surveys were conducted using a line transect technique (32 total transects) at six sites that varied in depth (0-5 m, 10-15 m, and 20-25 m) and substratum type (rocky boulders, rocky outcrop, vertical walls, and sand). Only two island grouper were observed during the entire study: one at the 10-15 m rocky bottom site and one at the 20-25 m rocky outcrop site. Island grouper mean densities were very low at both sites: 0.03 fish/100 m² rocky bottom; 0.20 fish/100 m² rocky outcrop.

Ribeiro (2008) studied fish assemblages in rocky reef habitats at three sites on the south coast of Madeira Island: a) Garajau Marine Reserve (termed as GMR) - a natural protected area, b) Caniçal - a natural unprotected area, and 3) Madeira airport riprap - an artificial unprotected area. UVC surveys were conducted at each site seasonally from Spring 2002 to Spring 2004 using three different sampling techniques (transect, point count, and visual fast count) in two depth strata (0-10 m and 10-20 m), and three bottom types (rocky boulders, wall, and platform) for a total of 183 dives. Island grouper were extremely rare in the shallow depth stratum (0-10 m) with relative abundances (RA) ranging from 0.0% - 0.02% and sighting frequency (SF) ranging from 0.0% - 4.0% across the different survey methods and sampling sites. Island grouper were more abundant and larger sized from 10-20 m, particularly in the GMR protected area along walls (RA= 0.56% and SF = 80%) and on platform bottoms (RA = 0.72% and SF = 100%). The island grouper was ranked as the 10th most numerically abundant species for surveys conducted in the GMR, deep stratum, on wall and platform bottom types. By

comparison, the dusky grouper was extremely rare across all depth strata, sites, and bottom types surveyed (RA 0.0% to 0.01%; SF 0.0% to 6.0%). While island grouper mean densities fluctuated widely over the 2-year study period (particularly within the GMR), there were no clear temporal patterns detected and most values were not statistically different from one another (Figure 7).



Figure 6. Map of Madeira archipelago (from Martin, 2008).

Canary Islands

Bortone et al. (1991) conducted the first quantitative study of the inshore fish communities of the Canary Islands archipelago. UVC sampling, using a point count technique (5 minutes, 100 m²), was conducted at 18 locations around El Hierro island (Figure 8) between July and August of 1989 (N = 360 total surveys). El Hierro has 105 km of coastline and is the most remote, least populated island in the archipelago (approximately 10,000 inhabitants and 80,000 tourists) (Canarian Institute of Statistics, ISTAC as cited in Bustos, 2008). The following measures of abundance were reported for island grouper (misclassified in this study as *M. rubra*): mean density = 0.24 fish/100 m² (standard deviation = 0.66); maximum fish per sample = 5; and frequency of occurrence = 16.8%. Island grouper were found at 15 out of the 18 locations surveyed around El Hierro, and accounted for less than 0.2% of all individual fish counted.

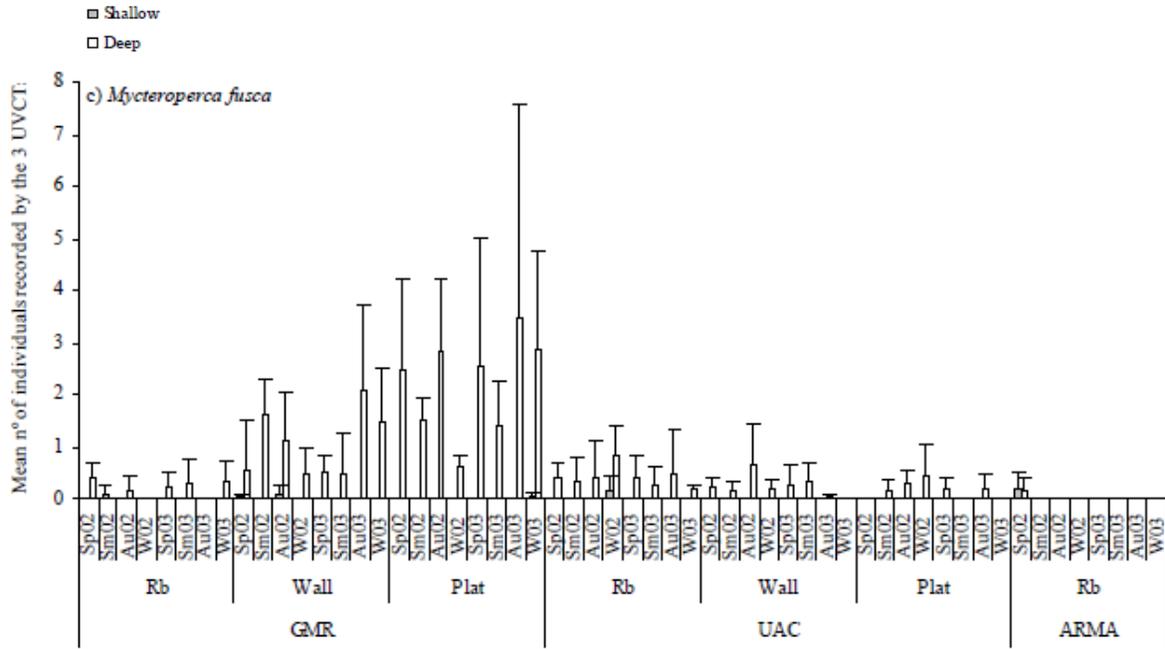


Figure 7. Mean island grouper abundance (+SD) per season (Sp – spring, Sm – summer, Au – autumn, W – winter) recorded from pooled UVC techniques (transect, point count, visual fast count) in three locations (GMR – Garajau marine reserve, UAC – unprotected area of Caniçal, and ARMA – artificial riprap of Madeira airport), depth strata and types of bottoms surveyed (Rb – rocky boulders, Wall, and Plat – platform) (from Ribeiro, 2008).

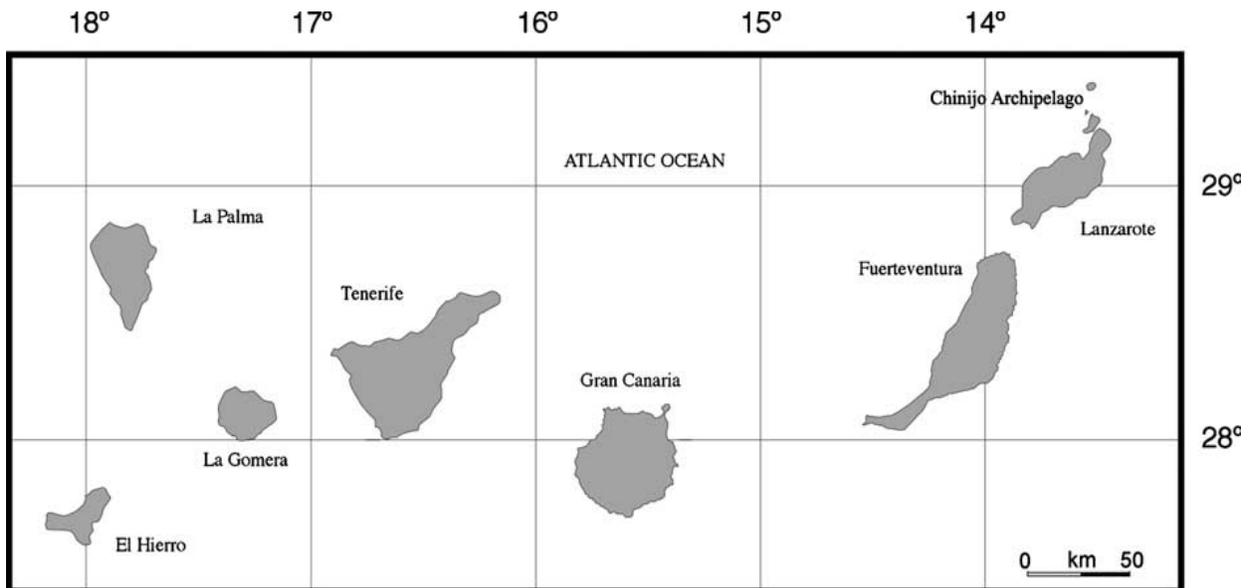


Figure 8. Map of Canary Islands archipelago (from Tuya et al., 2006a).

Falcón et al. (1996) studied littoral fish communities around the Canary Islands of Gran Canaria, Tenerife, Alegranza, and Fuerteventura. A UVC sampling technique similar to Bortone et al. (1991, see above) was used to survey 32 different locations around the four islands between June of 1990 and October of 1991. A total of 577 surveys were conducted, the large majority (436) on Tenerife. The following measures of abundance were reported for island grouper (misclassified in this study as *M. rubra*) across all islands: mean density = 0.10 fish/100 m² (standard deviation = 0.36); maximum fish per sample = 3; frequency of occurrence = 8.3%; and average estimated size 25.2 cm TL. Island grouper were found at 16 out of the 32 locations surveyed and accounted for less than 0.04% of all individual fish counted. In general, species considered economically important to the local fishing community were more abundant and larger at sampling locations around the less developed islands of Alegranza and Fuerteventura compared to the more developed and densely populated islands of Gran Canaria and Tenerife. Island grouper mean density was higher on Alegranza and Fuerteventura (0.19 fish/100 m²) than on Gran Canaria (0.09 fish/100 m²) and Tenerife (0.08 fish/100 m²), although these differences were not statistically significant.

Hajagos and Van Tassell (2001) assessed the inshore fisheries off Gran Canaria in 1996 using a UVC survey technique similar to Bortone et al. (1991, see above). A total of 211 surveys were conducted at seven different locations. Island grouper (misclassified in this study as *M. rubra*) were an extremely rare species in this study: mean density = 0.01 fish/100 m²; frequency of occurrence < 1% of surveys.

Tuya et al. (2004) conducted UVC surveys throughout the Canary archipelago (7 main islands plus the Chinijo islands) between February and May of 2003. Sampling was conducted at 36 locations (8 transects of 25 m per location) in water depths ranging from 10 m to 18 m. Overall mean density for island grouper in this study was 0.44 fish/100 m². Island grouper were observed at 20 out of the 36 sampling locations. Large differences in mean density were found across sampling locations (ranging from 0.00 to 7.63 fish/100 m²) with the highest densities found on the islands of El Hierro and La Palma.

As a follow-up to this study, Tuya et al. (2006a) conducted additional UVC surveys at 24 (out of the original 36) sampling locations from October 2003 through October 2004. All 24 sampled locations for this study were open to fishing (i.e., no-take reserves were not sampled). Island grouper mean density and mean biomass for the entire study (n = 768 total transects) were 0.32 fish/100 m² (SD 0.76) and 464.6 g/100 m² (SD 1,464.25), respectively. Island grouper mean biomass was greater than the three other serranid species in this study: dusky grouper, painted comber, and blacktail comber. Statistically significant differences in island grouper mean biomass and abundance were found among the different islands (Figure 9), with El Hierro being the largest and most abundant followed by Chinijo and La Palma (ANOVA p < 0.01). Significant differences were also found in island grouper mean biomass and abundance among locations within islands (Tuya et al., 2006a).

Bustos (2008) studied the relationship between island grouper abundance and habitat structural complexity within six study locations around the island of El Hierro. UVC surveys were conducted at 44 different sites (4 randomly selected transects at each site) from July through August of 2005. Structural complexity (IR) was measured within each transect using a

standardized volume index ranging from 0 - completely flat bottom, to 5 - highest structural complexity. Mean density of island grouper from the six study areas ranged from 0.20 to 0.81 fish/100 m², but no statistically significant differences were found among areas. Island grouper mean densities across different bottom types surveyed were also not statistically different from one another.

Bustos (2008) also studied island grouper abundance within the 700 km² La Graciosa Marine Reserve surrounding the Chinijo and North Lanzarote islands on the eastern margin of the Canary Islands archipelago. Surveys were conducted within seven study locations in November of 2006 using sampling methods similar to those used on El Hierro. The following mean densities (fish/100 m²) of island grouper were reported at sites within the reserve boundary: Rio 2.67; La Graciosa 2.18; Montana Clara 6.25; Roque Del Este 4.25; Alegranza 21.0. The author noted that the very high density recorded at Alegranza was due to a large group of island grouper observed at one sampled site. No island grouper were observed at two study areas outside of the reserve boundary (Lanzarote and near Jameos del Agua). Due to very small sample sizes (4 to 8 transects per area), the large differences found in mean densities across areas were not found to be statistically significant.

Vidal-López (2014) studied abundance and biomass of target fish species off Gran Canaria island during the Summer and Autumn of 2013. Sampling was conducted within two proposed (soon to be implemented) marine reserves (Cabron on the east side in 10-18 m; Canteras on the north-east side in 3-5 m), and within two nearby areas with similar depth, bottom type, wave climate, and oceanography as the proposed reserve areas. A UVC sampling technique was used involving four replicated 25 m long transects with each site sampled seven times. Within the proposed Cabron reserve, island grouper mean density was 1.5 fish/100 m² and the mean biomass was 458.6 g/100 m². These values were significantly greater than those recorded in the area just outside the proposed Cabron reserve: 0.13 fish/100 m² and 4.96 g/100 m² (Figure 10). Island grouper mean densities inside the proposed Cabron reserve site recorded in this study were also highly variable across sampling periods from a low of zero observed during T1 (July 26, 2013) and T7 (October 15, 2013) to a high mean of nearly 4.5 fish/100 m² during T6 (October 7, 2013). Large differences in mean densities recorded at the same site from week to week suggest natural variability and fish movement, although sampling error and non-sampling error associated with UVC technique may also play a role. Within the shallower 'Canteras' site (and nearby area) island grouper were extremely rare as only one fish was observed during all UVC sampling.

Sangil et al. (2013b) recorded biomass of demersal species of commercial interest around La Palma island from July 2008 to January 2009. Fish biomass data were recorded using UVC point-count survey technique at 51 sites (9 transects per site) ranging in depth from 5-20 m. Island grouper mean biomass was 103.1 g/100 m² (SE +/- 15.99), accounting for 5.1% of the total fish biomass (for the 26 target species recorded) and 34.5% of the apex predator biomass in this study.

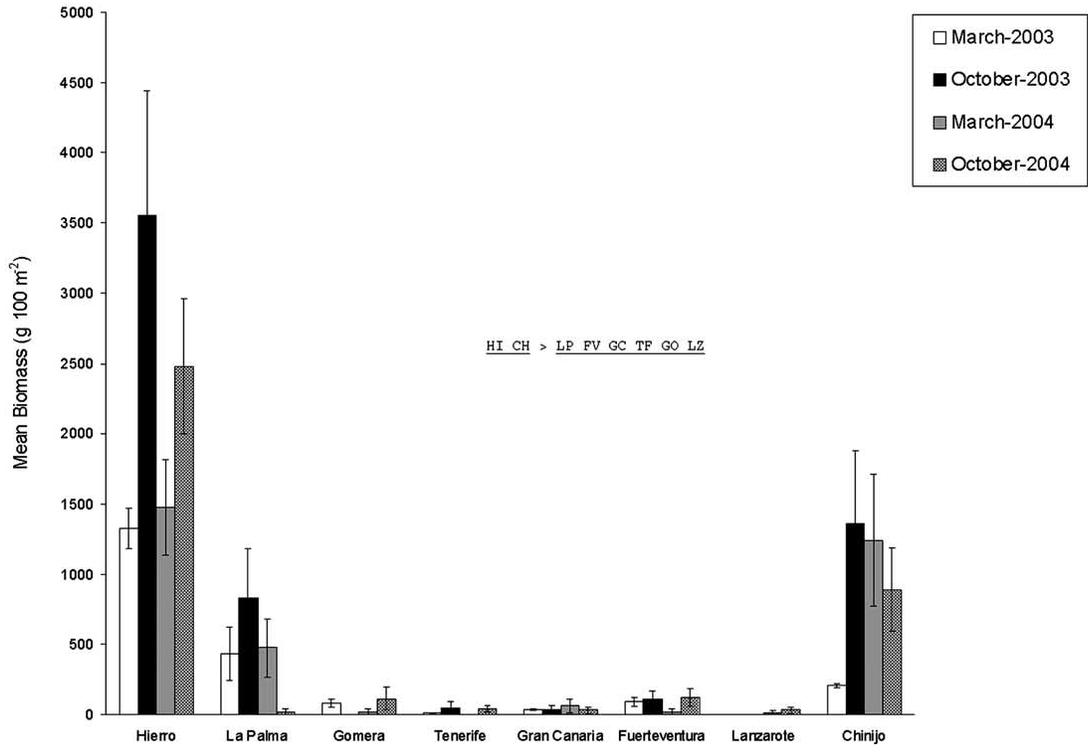
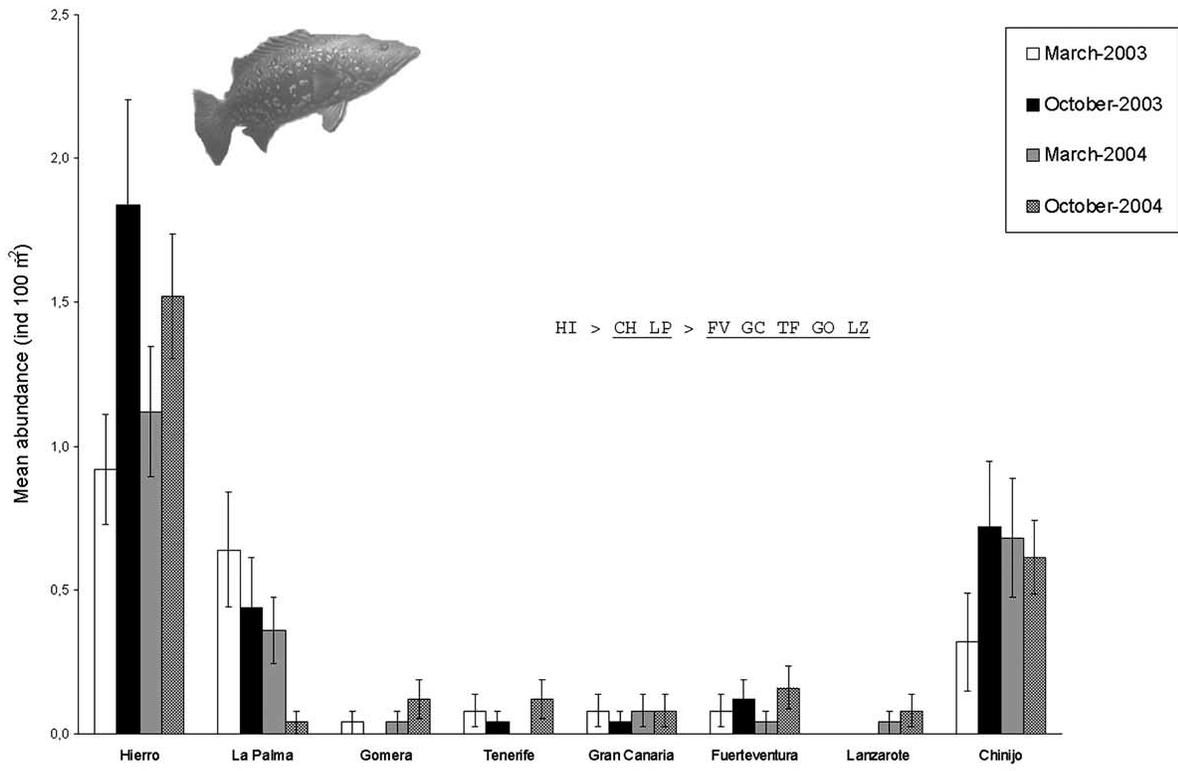


Figure 9. Island grouper mean abundance and biomass (\pm SE) by sampling period and island within the Canary Islands archipelago -- HI: Hierro, LP: La Palma, GO: Gomera, TF: Tenerife, GC: Gran Canaria, FV: Fuerteventura, LZ: Lanzarote, CH: Chinijo archipelago (from Tuya et al., 2006a).

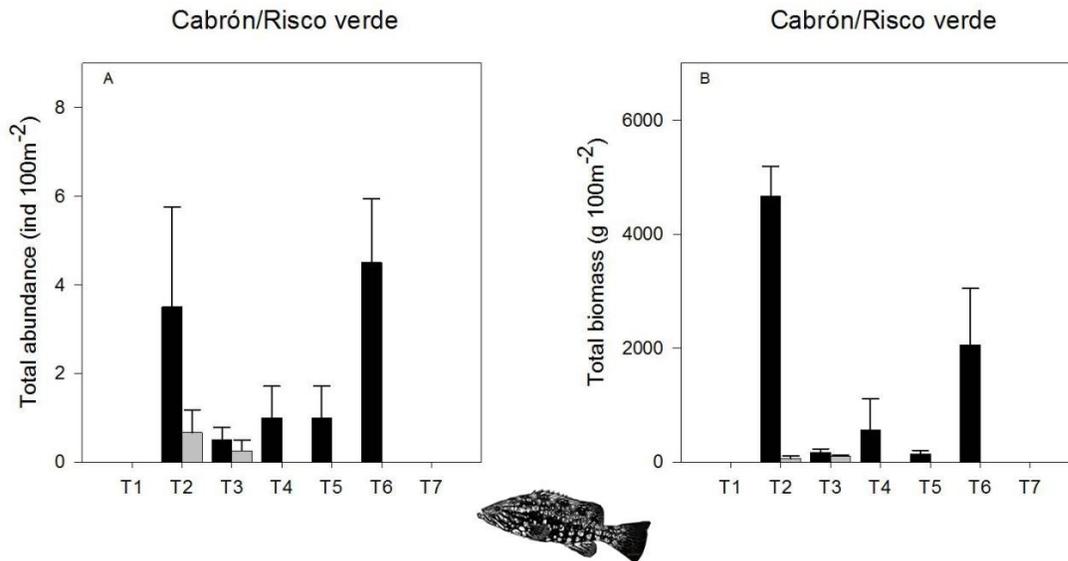


Figure 10. Abundance and total biomass (\pm SE) of the island grouper, *Mycteroperca fusca*, within Cabron proposed no-take area (black bars) and nearby area with similar features (gray bars) at each sampling time (from Vidal-López, 2014).

Toledo-Guedes et al. (2014) recorded fish species biomass at six locations (3 within the MPA) on the southwestern side of La Palma from 2009-2010. Snorkeling visual censuses were conducted (100 x 5 m transects) at depths from 1-5 m during four time periods: March 2009, October 2009, March 2010, and October 2010. Island grouper were extremely rare in this study: zero observed for all six locations in March 2009; observed at one location in October 2009 (mean biomass 28.7 g/100 m²); observed at two locations in March 2010 (mean biomass 1.4 and 2.9 g/100 m²); and observed at two locations in October 2010 (mean biomass 2.2 and 28.7 g/100 m²).

Island grouper were notably absent in a study of the role of seagrass meadows (*Cymodocea nodosa*) as nursery grounds for fish in the Canary Islands (Espino et al., 2011). Trawl surveys (n = 84 tows) conducted in 41 seagrass meadows from June through September 2003 around three islands (Gran Canaria, Lanzarote, and Fuerteventura) did not capture a single island grouper. The fishes found in this study were characterized by other rocky-bottom species (including three *Serranus* species), suggesting that sea grass meadows play an important role as nursery habitat for fingerlings and juveniles, and in maintaining fish species diversity in the Canary Islands. The absence of island grouper from seagrass meadow trawl surveys suggests that this species does not utilize seagrass meadows as nursery grounds, although it could also indicate extirpation or very low (undetectable) abundance of this species in the sampled areas.

Cape Verde

Freitas (2012) conducted an assessment of reef fish assemblages in the Santa Luzia Island marine reserve in the Cape Verde archipelago (Figure 11). UVC surveys (198 transects) were conducted using a line transect technique (20 m X 2 m) at 11 reef sites around the island in September and

October of 2009. Results for island grouper across all study sites were as follows: mean biomass 229.15 g/100 m²; mean density 0.825 fish/100 m²; frequency of occurrence 10% of all transects. Mean density ranged from 0.0 to 1.45 fish/100 m² across all sites except one (Ilheuzinho Reef) which had a mean density of 9.78 fish/100 m².

Summary of Abundance and Population Structure

Evaluation of island grouper distribution and abundance is difficult since most of the abundance information available is from the Canary Islands archipelago, with relatively little information from the Azores, Madeira, or Cape Verde archipelagos. Information on demersal fish assemblages is completely lacking for several main islands, and many smaller islets and seamounts, within the island grouper's range. Island grouper densities and relative abundance in these unstudied areas may be very different from those reported in the literature, particularly given the geographic isolation (or "partial" isolation) typical of archipelago ecosystems. Where studies have been conducted, sample sizes are often too small for detecting significant differences in mean density (or biomass) either across areas or over time, particularly for a rare species such as the island grouper.

There is a considerable amount of variation in island grouper mean densities reported in the literature previously cited. Island grouper were reported as being very rare in the two UVC studies of benthic fish communities in the Azores (Harmelin-Vivien et al., 2001; Bertocini et al., 2010). The closely related dusky grouper was much more common than the island grouper in these UVC studies, as well as in Azores artisanal fishery landings estimated for the period 1950-2010 (3,512 t versus 22 t [Pham et al., 2013]). This suggests that island grouper are naturally very rare compared to dusky grouper in the Azores, although it may also reflect differences in how each species has responded to fishing pressure and other anthropogenic threats. Based on limited information, island grouper also appear to be rare around Madeira island, with the possible exception of the Garajau Marine Reserve (Ribeiro et al., 2005; Ribeiro, 2008). However, unlike in the Azores, in Madeira island grouper were more common in UVC studies than the dusky grouper, which was extremely rare in all locations sampled. A mean density of 0.825 fish/100 m² was reported from one study in Cape Verde (Freitas, 2012). Since sampling was conducted within the only operationalized marine protected area (MPA) in Cape Verde on the uninhabited island of Santa Luzia (UNDP, 2010), target species densities from this study may not be representative of more densely populated areas throughout the archipelago with higher fishing pressure. Island grouper mean densities were also highly variable in studies conducted around the Canary Islands. The highest mean densities were reported around the lightly fished, remote island of El Hierro and within the designated marine reserves of La Graciosa (Chinijo islands) and La Palma. Island grouper were generally reported as being very rare on the more populous and heavily fished islands of Gran Canaria and Tenerife.

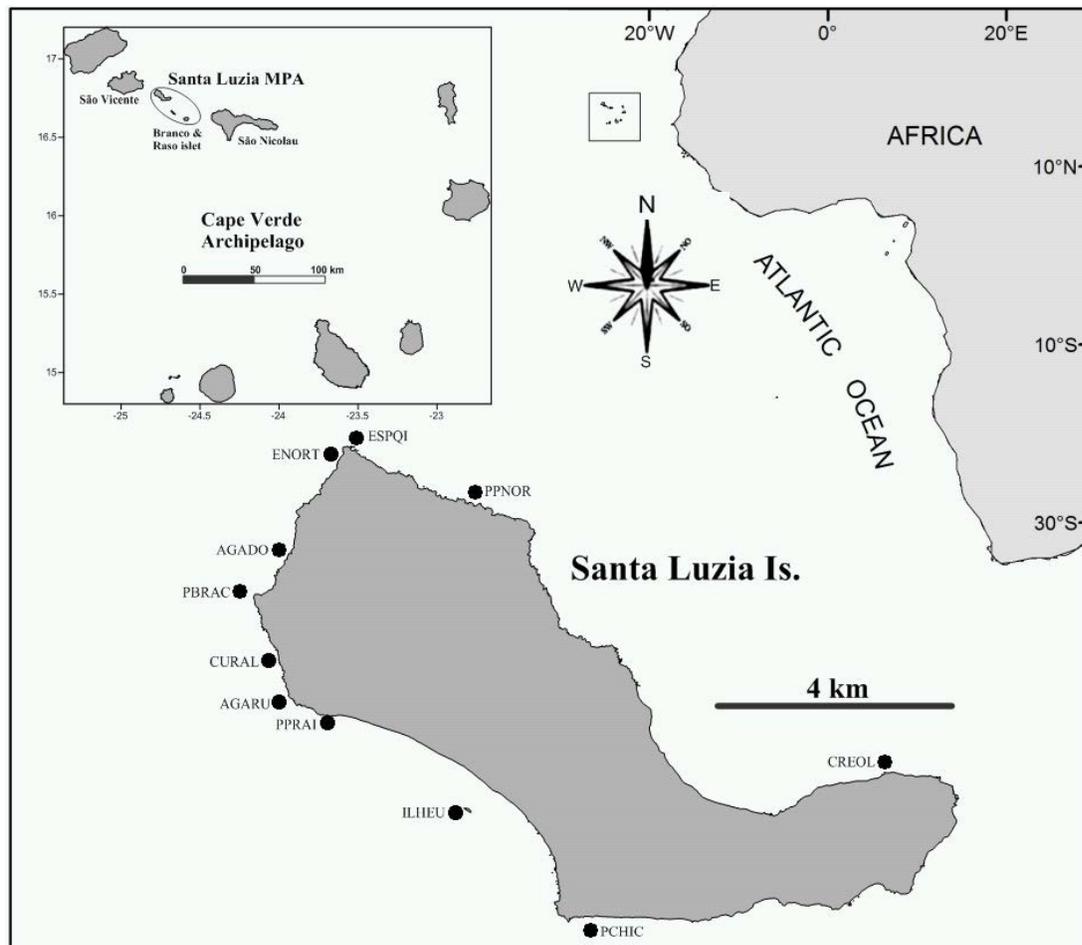


Figure 11. Map of Santa Luzia Island within the Cape Verde archipelago (from Freitas, 2012).

Assessment of Extinction Risk

Approach

Since the available information on island grouper does not support a quantitative assessment of extinction risk, a qualitative assessment was conducted for this report. I considered demographic risks to the island grouper, similar to approaches described by Wainwright and Kope (1999) and McElhany et al. (2000). In this approach, the collective condition of individual populations is considered at the species level according to four demographic viability risk criteria: abundance; growth rate/productivity; spatial structure/connectivity; and diversity. According to Section 4(a)(1) of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered because of any of the following factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Specific threats to the island grouper from any of these five factors were considered. All of the available scientific and commercial information is presented here, and an assessment is made regarding the likelihood

that each particular demographic factor or threat is contributing, on its own or in combination, to the island grouper risk of extinction.

Scientific conclusions about the overall risk of extinction faced by the island grouper are based on my evaluation of the species' demographic risks and Section 4(a)(1) threat factors. Assessment of overall extinction risk considered the likelihood and magnitude of each particular factor, synergies among contributing factors, and the cumulative impact of all demographic risks and threats on the species. I used the following 3-item qualitative scale for assessment of overall extinction risk:

- Low risk - it is unlikely that this species is at risk of extinction due to trends in abundance, productivity, spatial structure or diversity; however, threats may alter those trends, but not by enough to cause the species to be influenced by stochastic or compensatory processes.
- Moderate risk - the species exhibits a trajectory indicating that it is approaching a level of abundance, productivity, spatial structure, and/or diversity that places its persistence in question. A species may be at moderate risk of extinction due to declining trends in abundance, productivity, spatial structure, or diversity and/or threats that inhibit the reversal of these trends.
- High risk - the species is at or near a level of abundance, productivity, spatial structure, and or/diversity that places its persistence in question. It faces clear threats that are likely to create such demographic risks and inhibit their reversal.

I do not make recommendations as to whether the island grouper should be listed as threatened or endangered in this report. Determination of a species' ESA listing status is a decision that includes the findings and conclusions in the status review report as well as consideration of existing conservation efforts, the certainty of implementation and effectiveness of those conservation efforts not yet implemented or not yet shown to be effective, as well as other management considerations.

Analysis of Demographic Risk Factors

The approach of considering demographic viability criteria to help frame the evaluation of extinction risk is widely used in NMFS status reviews (see NMFS Office of Protected Resources website¹ for links to these reviews). These viability criteria reflect concepts that are well founded in conservation biology and that individually and collectively provide strong indicators of extinction risk.

Abundance

Population abundance is an important determinant of risk, both by itself and in relation to other factors. Small populations are subject to a host of risks intrinsic to their low abundances, while large populations can exhibit a greater degree of resilience (McElhany et al., 2000). As slow growing, late maturing, high level predators, many grouper species are naturally rare (Heemstra and Randall, 1993; Morris et al., 2000). Based on an extensive literature review of the

¹ Source - <http://www.nmfs.noaa.gov/pr/species/>

abundance of species in the subfamily Epinephelinae, Morris et al. (2000) classified 23 species as “rare,” 23 species as “intermediate” (i.e., common in some areas but rare in others), and 8 species as “common.” Island grouper were one of 31 grouper species for which there was not enough information (15 years ago when this paper was published) to qualitatively rank in terms of abundance.

There are no population abundance estimates available for island grouper. Results of UVC sampling studies indicate that island grouper are either not found or are present at very low densities in some parts of its range, particularly in the Azores and heavily fished areas of the Canary Islands. Higher mean densities have been reported for island grouper from a few study sites, particularly areas less impacted by fishing pressure such as “no-take” marine reserves or remote, sparsely populated islands (see “Life History and Ecology: Abundance and Population Structure” above for more details). However, these areas with relatively higher abundance are typically small, patchily distributed, and physically isolated from one another. While island grouper have been found in relatively greater abundance in a few small areas, the available data do not support a conclusion that this species is “common” in any parts of its range. The cumulative UVC data collected over the past 25 years from locations across the Macaronesian region, presented in the literature cited above, suggest that the island grouper is a rare species in its natural environment, and is very rare in areas with heavy fishing pressure. Low density and relative abundance, combined with the island grouper’s restricted geographic range and narrow depth range (Morris et al., 2000), indicate that small population size is likely a risk factor for this species which could be disproportionately affected by coastal development or a stochastic catastrophic event (Sadovy de Mitcheson et al., 2012).

Evaluating trends in island grouper abundance over time is problematic as information on this species is sparse and time series datasets and long-term studies are lacking. The available UVC studies do not support a comparative analysis of temporal trends in island grouper mean densities over time for the following reasons: very small sample size of studies from any particular island or archipelago suitable for comparison (i.e., too few data points), major gaps in the time series, methodological differences between studies, and lack of precision on abundance estimates. Instead, declines in island grouper abundance over time have been inferred based on UVC studies comparing mean density (or mean biomass) between study locations with different levels of fishing pressure (Tuya et al 2006a; Bustos, 2008; Ribeiro, 2008; Sangil et al., 2013a; Sangil et al., 2013b). Results indicate that island grouper are relatively more abundant in areas where fishing activities are either prohibited (i.e. “no-take”) or limited with gear or sector restrictions, or in unpopulous areas where relative fishing intensity is generally low. While recreational and artisanal fishing pressure on this species has reduced overall abundance (Tuya et al., 2006a), and in some heavily fished areas this reduction is likely significant, available data are insufficient to quantitatively assess the magnitude of this decline.

Growth Rate / Productivity

The slow growth, late maturation, large size, and long life span (30-40 years) observed in the island grouper are characteristic of evolutionary strategies and adaptations of a specialist species that assigns a high proportion of its energy to non-breeding activities (Bustos, 2008). Traits associated with growth, reproduction, and other life history characteristics of the island grouper make this species particularly susceptible to overfishing (Bustos, 2008; Bustos et al., 2009;

Saavedra, 2011; Diogo and Pereira, 2013a). Saavedra (2011) used a scale developed by FAO to characterize fishing vulnerability of target species in the Canary Islands. Input parameters used for this scale included age at maturity, longevity, ratio of natural to total mortality, growth rate, sexual strategy, and sex ratio. Island grouper vulnerability was rated as either “high” or “very high” for all six parameters individually, and “very high” overall.

In protogynous hermaphrodites, such as the island grouper, the largest individuals are, in order, terminal males, individuals undergoing sexual transition, and the largest females next in line for sexual transition. Selective removal of these groups at high rates can lead to decreased productivity of a population. Reported sex-ratios in the literature for species within the genus *Mycteroperca* indicate that the heavy imbalance towards females is partly due to fishing pressure which targets the largest, longest-living specimens (Bustos et al., 2010). Island grouper may be particularly vulnerable to over-fishing due to the reduction in the species’ potential reproductive capacity caused by the decrease in the number of males in the population (Huntsman and Schaaf, 1994; Bustos et al., 2010). As the relative numbers of terminal males fall, females may have difficulty finding a terminal male to spawn with even if some remain (Hawkins and Roberts, 2003). In addition, sexual transition takes time and energy, including energy expended on social interactions and competition among females vying for dominance. Since removal of terminal males by fishing will result in more sexual transitions, overall population fitness may be negatively impacted.

Spatial Structure / Connectivity

Spatial structure is composed of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al., 2000). A population’s spatial structure depends fundamentally on habitat quality and spatial configuration, and the dynamics and dispersal characteristics of individuals in the population. Habitat loss and fragmentation are among the principal factors leading to biodiversity loss (Pimm and Raven, 2000).

Archipelago systems typically contain highly fragmented, patchy habitats (Martins et al., 2008) characterized by a rich endemic marine biodiversity due to their isolation from continents and clearly established spatial limits (Medina et al., 2007). In addition to isolation created by distance between islands, the vertical dimension associated with bathymetry plays a varied and complex role in archipelago ecosystem fragmentation through its interaction with hydrodynamic processes such as wind-driven circulation, turbulent mixing processes, and buoyancy forces (Figure 12) (Medina et al., 2007). Islands and groups of islands within the Macaronesian region are geographically dispersed, highly fragmented, and physically isolated by depths often exceeding 3000 m. With a few exceptions (i.e., Lanzarote and Fuerteventura in Canary Islands, Faial and Pico in Azores, and some smaller islets), the shallow platforms around most islands in the region are not continuous, and as a result each island has its own independent shallow, benthic population (Sangil et al., 2013b). Therefore, shallow water, demersal fish populations may be limited and independent on each island, and for most species there is no adult inter-island migration (Cuyás et al., 2004). This physical barrier may prevent the migration of adults between islands but not necessarily the drift of eggs and larvae, resulting in what could be considered “partial” geographic isolation of different island fish stocks. For demersal species within archipelago ecosystems, the main significant interactions between physical and

hydrodynamic features that affect species dispersal and distribution probably occur during spawning or early life stages (Medina et al., 2007).

There is very limited information in the literature on the spatial structure, connectivity, or dispersal characteristics specific to the island grouper. As noted above, island groupers are rare in many areas, and the spatially limited areas with relatively higher abundance, as reported in the literature, are patchily distributed throughout the species' range. Geographic distance and bathymetry, along with other physical factors, likely induce various degrees of isolation between island populations of demersal fish species (Medina et al., 2007).

Medina et al. (2007) evaluated the effects of physical isolation between islands (i.e., geographic distance and depth) on the spatial and temporal structure and variability of exploited demersal fish communities in the Cape Verde archipelago. Artisanal fisheries landings were used to reflect the spatial distribution, abundance and diversity of demersal species throughout the archipelago. CPUE data were collected monthly from 1996-2002 from 1,354 vessels utilizing 260 fishing sites. Overall results suggest that for the Cape Verde archipelago, physical isolation is an important factor that drives ecological isolation among islands. Ecological isolation between islands varies throughout the year and appears to be affected by different hydrodynamic regimes between cold and warm seasons. Species were grouped into one of four species assemblages that were related to groupings of islands based on geographic location (northern, southern, and eastern). Island grouper was the only species (out of 18 in this study) that was not associated with a particular fish species assemblage. This result may be due to small sample sizes of island grouper (i.e., rareness in landings) compared to other species, although the authors

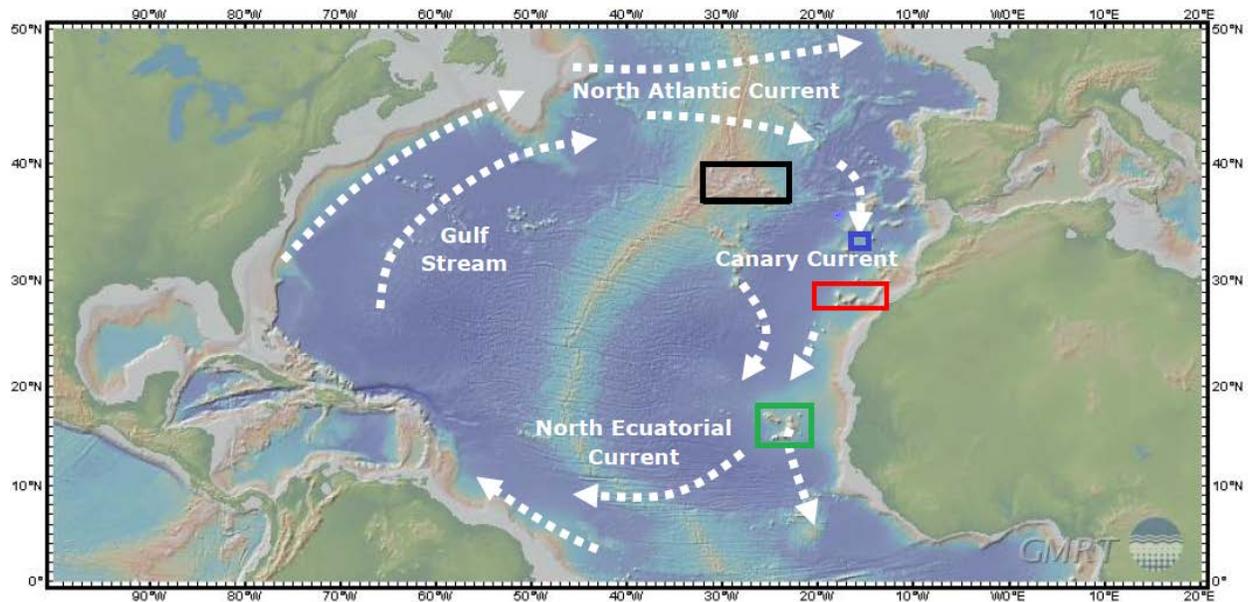


Figure 12. Main currents and seafloor morphology in Central Atlantic. Rectangles indicate the approximate location of the four archipelagos that comprise the island grouper known range: black = Azores, blue = Madeira, red = Canaries, and green = Cape Verde (adapted from Popescu and Ortega-Gras, 2013; bathymetry from Marine Geoscience Data System and currents from American Meteorological Society).

do not postulate an explanation. Based on their results, Medina et al. (2007) suggest that, for conservation and management purposes, fish populations from spatially distinct islands or island groups be considered as discrete management units.

Studies by Cuyas et al. (2004) and Castro et al. (2002 as cited in Cuyas et al., 2004) suggest that the Canary Islands population of blacktail comber (*Serranus atricauda*) consists of several local stocks with phenotypic and population dynamic features that differ between the islands. Similar variations may be present in other demersal species, such as island grouper, due to the physical barrier between islands within the Canary Islands archipelago. Although the spatial distribution, diversity, and phenotypes of demersal species have not been compared across the Macaronesian islands region, results from these studies suggest an even higher degree of isolation and phenotypic variation is likely between fish populations across the widely dispersed archipelagos that comprise the island grouper range.

Information pertaining to localized, near-shore, or intra-island movement of island grouper is very sparse. The formation of spawning aggregations by island grouper, as suggested by personal communications, would necessitate the movement of relatively large numbers of mature fish to predictable locations at predictable times of the year. Distances traveled by other grouper species from resident locations to spawning aggregation sites are known to vary greatly, but can be as large as 100 km (Sadovy de Mitcheson et al., 2008). Spawning aggregations serve as a beneficial reproductive trait for rare species in the search for mates, and by connecting local populations of fish whose resident locations do not overlap. However, such benefits may be outweighed by the increased vulnerability of such aggregations to fishing overexploitation (Sadovy de Mitcheson et al., 2008).

Herrera et al. (2002) compared fish community structure off the southern coast of Gran Canaria (Canary Islands) before and after creation of a large oceanic artificial reef. The artificial reef, deployed in March 1991, is composed of 85 concrete modules (1.2–5 t and 0.8–2 m high) and is located on sandy bottom 3.5 km from the coast. UVC surveys were conducted just before deployment (December 1990 to March 1991) on three neighboring biotopes (shallow rocky coast; sandy bottom near reef site, and isolated natural reef 3 km from reef site) by Haroun et al. (1994) and on the artificial reef from December 1991 to February 1995 by Herrera et al. (2002). Island grouper were not found in any of the three surrounding areas surveyed prior to deployment but were subsequently found on the offshore artificial reef. These results suggest island grouper were able to recruit to the artificial reef from more distant locations (i.e., > 3 km), although the distance traveled or mechanism by which this occurred is unknown.

Diversity

I did not find any studies or information pertaining to genetic diversity of island grouper. Factors that may impact diversity include: 1) island grouper is a rare species with a small population size and very low densities in many areas, and 2) island grouper are endemic to archipelago systems which typically contain highly fragmented, physically isolated (or partially isolated) marine habitats.

Analysis of ESA Section 4(a)(1) Factors

The following provides information and analysis on each of the five ESA Section 4(a)(1) threat factors as they relate to the island grouper.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Demersal fish populations around volcanic islands may be particularly vulnerable to habitat related threats as they are typically confined to a narrow band within a few kilometers from shore due to the surrounding bathymetry. Various human activities throughout the Macaronesian region can negatively impact near-shore, rocky marine habitats occupied by island grouper. Increased anthropogenic pressure on the more densely populated Macaronesian islands (Madeira island, and Tenerife and Gran Canaria in the Canary Islands) has resulted in continuous modification and degradation of inshore habitats, placing new and unprecedented demands on coastal marine resources (Hajagos and Van Tassell, 2001; Ribeiro, 2008). Potential threats to island grouper habitat include ecosystem changes driven by overfishing, destructive fishing practices, physical alteration of the coast, pollution, and the effects of global climate change.

The island grouper is a demersal species primarily found near the ocean bottom in areas with high structural complexity (or “roughness”) and benthic cover (Bustos, 2008; Monteiro et al., 2008; Sangil et al., 2013b). As a principal engineer organism on shallow rocky bottoms, upright seaweeds provide the necessary habitat complexity and benthic cover to support and maintain equilibrium of natural assemblages (Hernández et al., 2008; Clemente et al., 2010; Sangil et al., 2013b). In the Canary Islands, the natural balance between seaweeds, herbivores, and predators has been disturbed due to the fishing depletion of predators (e.g., sparids and labrids) of the sea urchin *Diadema africanum*, the most important herbivore of sublittoral rocky bottoms (Hernández et al., 2008; Clemente et al., 2011). This has resulted in an ecosystem imbalance whereby sea urchin populations have increased while cover of upright seaweeds and algae have decreased (Tuya et al., 2004; Hernandez et al., 2008; Clemente et al., 2011; and Riera et al., 2014). Seaweed beds have declined throughout much of the Canary Islands archipelago, and are now only found in abundance in restricted fishing areas, remote islands, or areas where prevailing winds and currents limit fishing pressure (Sangil et al., 2013b). Steady declines in benthic cover of brown macroalgae (*Fucus spiralis* and *Cystoseira spp.*) in the Canary Islands have been linked to growing sea urchin populations in combination with rising sea surface temperatures (Hernández et al., 2008). Population declines and increased fragmentation of the endemic red alga *Gelidium canariense* have also been observed in Tenerife and Gran Canaria during the last 20 years (Bouza et al., 2006). Canopy-forming macroalgae may ameliorate the effects of a range of disturbances on understory assemblages, thus enhancing the resistance of associated systems (Bertocci et al., 2014). The loss of canopy forming macroalgae, and consequent increased environmental stress on associated organisms, could result in drastic reduction or local extinction of understory species unable to survive harsh environmental conditions without the protective canopy (Bertocci et al., 2014). These studies suggest that, in addition to the direct impact of fishery removals of island grouper, fishing can initiate trophic cascades that may modify and degrade island grouper habitats or preferred microhabitats.

Destructive fishing methods can also negatively impact demersal fish habitat. Small-scale artisanal fishermen in Cape Verde still use dynamite to catch baitfish, even though the practice is now illegal (Trindade-Santos et al., 2013). Dynamite fishing began in Cape Verde in the 1950's but decreased after 1985 when fishermen were encouraged to use purse seines as an alternative to explosives (Silva 2009 cited in Trindade-Santos et al., 2013). An estimated 50% of the total baitfish landings from 1950 to 1985 were from dynamite fishing, compared to 10% in 2010 (Ministry of the Environment Agriculture and Fisheries, 2004 cited in Trindade-Santos et al., 2013). The use of illegal explosives by fishermen has also been reported on the island of Madeira, although the extent and negative impacts of this practice are unknown (Ribeiro, 2008).

Large-scale coastal development began in the Canary Islands in the early 1970's to meet the needs of a growing tourist industry (Hajagos and Van Tassell, 2001). Similarly, the Madeira island coast has been extensively armored and developed in the past two decades (Ribeiro, 2008). Artificial harbors, marinas, beaches, ripraps, rubble mounds, and hotels were constructed on these islands with few environmental precautions, resulting in massive alterations to the shoreline and siltation of nearshore benthic communities (Hajagos and Van Tassell 2001). Baseline (pre-development) studies of the near-shore marine communities in these heavily developed areas are lacking and, therefore, the impacts of these habitat changes on marine fish populations in general, and the island grouper in particular, are largely unknown.

Pollution from a variety of sources also threatens marine ecosystems in the Macaronesian region. In the Canary Islands, land-based sources of pollution include organic and inorganic pollutants from developed areas and farms (mainly banana and tomato), brine releases from desalination plants, and thermal pollution from power plants (Riera et al., 2014). Other sources include nitrogenous waste from aquaculture, pollution derived from ship traffic, and extraction of construction materials from the seabed (Riera et al., 2014). Sharp declines in coverage of the red algae *Gracilaria cervicornis* over the last 10 years have been linked to coastal pollution from desalination plants and sewage from pipelines (Riera et al., 2014). On the island of Madeira, pollution from raw sewage discharges, sand mining, and sediment run-off severely decreases water clarity which affects algae production (Ribeiro, 2008). The direct impacts of different pollution sources on demersal fish populations in the Macaronesian region are not well-studied. The presence of continuous coastal currents around islands in this region likely facilitates the dispersion of pollutants (Riera et al., 2014). Thus, while localized impacts may be acute near highly concentrated point sources, broader and long lasting impacts of coastal pollution in this region have not been identified.

Heavy metals naturally occur in seawater in very low concentrations, but global population growth and industrial development have increased contamination of heavy metals in the marine environment. High concentrations of certain metals are found in long-lived, high trophic level species due to the effects of bioaccumulation. Lozano et al. (2009) analyzed the levels of lead and cadmium in island grouper from commercial fishery samples from the Canary island of Lanzarote (Table 1). Although levels of both metals were well below legal limits for consumption, it is unclear from this study whether accumulation of these metals presents a threat to island grouper fitness or survival.

Table 1. Concentrations of lead (Pb) and cadmium (Cd) (median value \pm standard deviation) in various tissues of island grouper (from Lozano et al., 2009).

Tissue	n	Pb (ug kg ⁻¹ wet weight)	n	CD (ug kg ⁻¹ wet weight)
Brain	3	792.00 \pm 983.30	3	65.00 \pm 91.03
Gills	11	416.90 \pm 539.40	11	6.78 \pm 11.10
Heart	11	83.40 \pm 59.30	11	73.75 \pm 38.84
Kidneys	10	62.15 \pm 54.58	10	113.78 \pm 1297.6
Liver	16	109.10 \pm 135.30	16	656.00 \pm 922.80
Muscle	18	65.70 \pm 104.90	19	10.70 \pm 7.93
Skin	3	134.90 \pm 195.00	3	10.87 \pm 7.43
Spleen	2	360.00 \pm 279.30	2	440.50 \pm 143.54
Vertebrae	17	4.97 \pm 8.53	17	23.34 \pm 58.35

Certain changes are likely to occur in the world's oceans due to long-term changes in global mean temperature and possible anthropogenic impacts that could pose potential future threats to island grouper habitats. The principal changes anticipated by the year 2100 are summarized as follows: 1) ocean temperature increase of 0.5 - 2.5°C (IPCC, 2013), 2) sea level rise of 0.5 -1.4 m (Rahmstorf, 2007), and 3) ocean acidity increase with pH falling 0.3–0.4 pH units due to increasing atmospheric and oceanic CO₂ (Doney et al., 2009). Warmer oceanographic conditions associated with climate change (combined with overfishing) have likely contributed to the population increases of *D. africanum* discussed above (Hernández et al., 2010). Brito et al. (2005) found 24 out of the 30 new records of littoral bony fishes reported between 1991 and 2005 from two Canary Island marine reserves (La Graciosa in Chinijo islands and La Restinga in El Hierro) were species with tropical origins. The emergence of tropical species in subtropical latitudes has also been reported in Madeira and the Azores (Brito et al., 2005). However, the impacts of progressive tropicalization on coastal marine ecosystems in the Macaronesian region, or on particular species for that matter, are widely unknown.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

As discussed above (see “Analysis of Demographic Risk Factors”), island grouper are highly susceptible to overfishing due to their limited range and a combination of life history characteristics (Bustos, 2008; Bustos et al., 2009; Saavedra, 2011; Diogo and Pereira, 2013a). Certain behavioral traits, which are common in groupers, may also add to this species' vulnerability to fishing. Territoriality, site specificity, and the formation of spawning aggregations often result in groupers being an easy target for fishermen (Randall and Heemstra, 1991; Domeier and Colin 1997), although these traits have not been studied or well documented in the island grouper. Spawning aggregations, in particular, are highly vulnerable to fishing due to their spatial and temporal predictability and to the large increase in catchability that often occurs when fish aggregate (Sadovy and Domeier, 2005). There are documented examples of sharp population declines resulting from fisheries specifically targeting grouper aggregations (Colin, 1992; Sala et al., 2001; Hamilton and Matawai, 2006; Sadovy de Mitcheson et al., 2012).

Groupers are highly prized by commercial and artisanal fishermen for the quality of their flesh, and most species fetch high market prices (Heemstra and Randall, 1993). Ribeiro (2008) noted that island grouper have excellent eating qualities and are a very high priced species in Madeira's fish markets. The economic value of island grouper is also a factor that likely contributes to overutilization of this species.

The threat of island grouper overutilization from fishing is discussed below for each of the four archipelagos that comprise the species' range.

Azores

The Azorean fishery is characterized as predominantly small-scale and artisanal, although recently some operations have become larger and more commercial. In 2005, the artisanal fishery in the Azores consisted of 601 boats, employed 1,583 fishermen, and landed an estimated 4,608 t of fish (Carvalho et al., 2011). Primary fishing gears used for demersal species are handlines and bottom longlines. Traps and gillnets are also used but these gears represent a very small component of the artisanal fishery in the Azores (Morato, 2012).

The bottom longline and handline artisanal fishery for demersal species accounts for a significant portion of the total fishery landings, and is by far the highest valued fishery, in the Azores archipelago (Figure 13). Bottom longlines were first introduced to the Azores demersal fishery in the 1980's (Morato, 2012). This gear, in combination with increased fishing effort and capacity, resulted in the rapid decline of several demersal fish stocks in the Azores (Santos et al., 1995). The black sea bream, one of the most important demersal species, showed a 50% decline in CPUE from 1983-1989 (Santos et al., 1995). The use of bottom longlines was subsequently banned in 2000 in the Azores coastal areas within 3 miles from shore. As a consequence, many smaller artisanal boats switched to predominantly handlines for targeting demersal fish species.

Since the 1970's, all demersal fish landings in the Azores are required to pass through one of the fishery auction houses distributed throughout the archipelago, all owned by the company Lotacor SA (Pham et al., 2013). Lotacor SA is responsible for transferring all landings data to local authorities where it is compiled and eventually reported to the Portugal National Institute of Statistics (INE). The INE produces annual fishery statistics reports that include species level landings data for the Azores. Scientific fish names are not used in these reports as data are provided by Portuguese common name only. The common name 'badejo' is used on the Portuguese mainland to describe several species of *Mycteroperca*, but in the Azores and Madeira it most likely refers to the island grouper. Therefore, I assume that landings reported by the Portugal Institute of Statistics as 'badejo' for the Azores and Madeira archipelagos refer to the island grouper. Reported landings of island grouper for the Azores archipelago were around 2 t in 2000 and less than 1 t for every year from 2001-2013 (INE, 2015). Official data from the INE indicates a sharp and steady decline in combined "grouper" landings in the Azores from 2002 to 2013 (Figure 14). The combined grouper category includes species of *Epinephelus* and *Mycteroperca*. Grouper landings, which were as high as 99 t in 2003, declined to 26 t in 2013. Combined grouper landings accounted for an estimated 1.3% of all demersal fish landings weight in the Azores artisanal fishery in 2010 (Morato, 2012). The declining trend suggests that groupers, in general, are being overfished, which would likely have negative implications for the

island grouper. Without effort data it not possible to say definitively that the decrease in landings is due to a decline in population abundance. For example, it is unclear what impact the 2000 ban on bottom longlines within three miles from shore had on fishermen's selection of fishing areas or target species, factors which may have contributed to the decline observed in grouper landings. However, total demersal species landings from 2000-2010 are consistently around 4,000 t (Figure 13, BLL/HL). This suggests that directed effort for demersal species did not decline during the period when grouper landings declined sharply as shown in Figure 14.

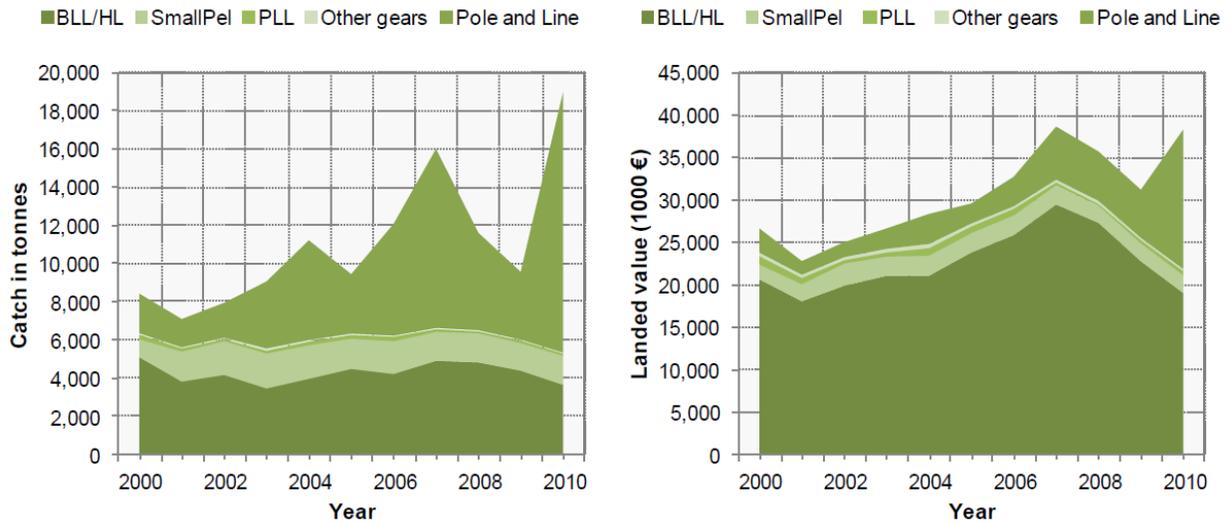


Figure 13. Annual landings (left) and landed value (right) of major fisheries components in the Azores for the period 2000-2010. BLL/HL = bottom longline / handline, SmallPel = small pelagic fisheries with surrounding nets, and PLL = pelagic longline (from Morato, 2012).

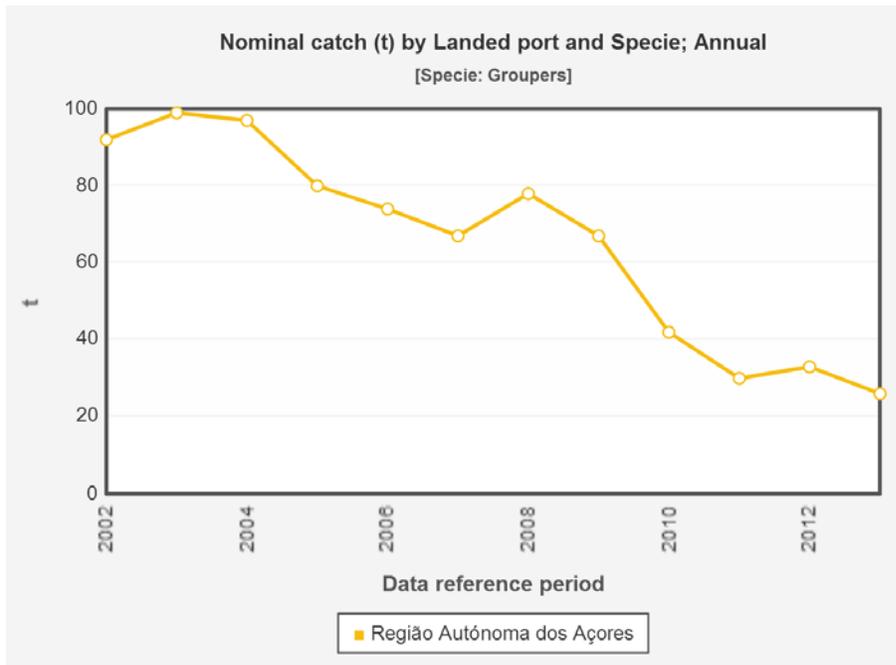


Figure 14. Azores landings (metric tons) of groupers combined from 2002-2013 (Source: National Institute of Statistics of Portugal website).

Pham et al. (2013) estimated Azores fishery landings from 1950-2010 based on the following data sources: 1950-1980 Portugal National Institute of Statistics; 1981-1992 Lotacor SA fisheries auction house database; and 1993-2010 University of the Azores Department of Oceanography and Fisheries in conjunction with Lotacor SA. Catch data at higher taxonomic levels (e.g., “groupers”) were disaggregated to the species level according to relative proportions for known years, expert knowledge, and various reports and gray literature to account for unknown or inaccurate taxonomic resolution of early statistics. Based on this approach, the total landings of island grouper in the Azores from 1950-2010 was estimated to be 22 t or 0.36 t per year. Estimated landings of island grouper in the Azores over this time period were much smaller than estimated landings of the closely related dusky grouper (3,512 t).

The popularity of recreational spearfishing has increased tremendously in the Azores in recent decades (Figure 15). However, data from this fishery are lacking and the impact of recreational fishing, in general, on demersal resources in the Azores is not well studied. Diogo and Pereira (2013a) conducted a characterization study of spearfishing activity in Ponta Delgada, the capital of São Miguel Island, the most populated island in the archipelago. Fishing activity was monitored from August 2001 to May 2002 using an access point intercept survey methodology. Surveys were conducted on 124 days when conditions were suitable for spearfishing. During this time 281 total spearfishing trips were observed, 220 personal interviews were conducted, with only 1 refusal. A total of 105 fishermen were interviewed: 70 were interviewed once and 35 were interviewed multiple times. The average effort per trip was 1.7 hours and the average number of fishing trips per year was 22. Nearly all spearfishermen interviewed (96%) were inhabitants of the island. While only 9.5% of those interviewed indicated they sell their catch, these fishermen accounted for 27% of the trips and 59% of the catch recorded. This suggests that some recreationally licensed spearfishermen are more commercial (or semi-commercial) in nature, even though their landings may not be reported through the normal commercial reporting system. A total of 9 island grouper (mean weight = 0.76 kg; mean length = 38 cm) were captured throughout the study period. By weight, island grouper accounted for less than 1% of the total biomass of finfish captured (775.7 kg) with spear guns in the survey. The mean length of island groupers captured was only slightly larger than the size at first maturity (Bustos et al., 2010). Mean lengths of other top predators in the study (*E. marginatus*, *S. viridensis*, *S. rivoliana* and *S. atricauda*) were also close to size at first maturity for these species. Eight dusky grouper (*E. marginatus*) were also caught in this study, even though spearfishing for this species is prohibited in the Azores. In general, a very small percentage of the catch was composed of species with a high to very high fishing vulnerability score. These results suggest that abundances of species vulnerable to fishing (including island grouper) within the study site have been significantly reduced due to fishing pressure (Diogo and Pereira, 2013a). This finding agrees with patterns typical of areas with relatively high spearfishing effort, characterized by low abundance of larger predators, which affects the highest potential spawning output (Jouvenel and Pollard, 2001).

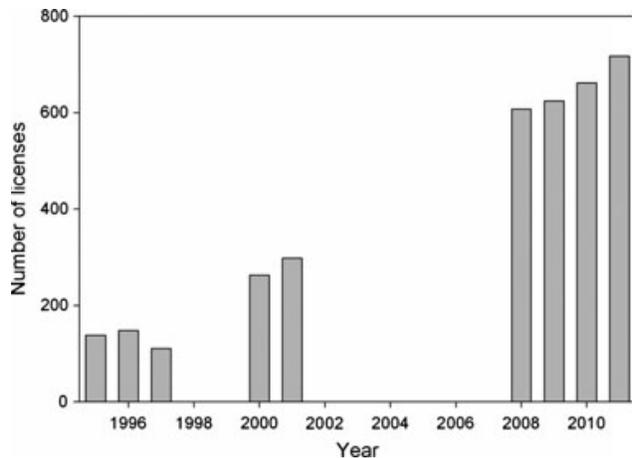


Figure 15. Number of recreational spearfishing licenses sold in São Miguel Island from 1995-2011. No data available for the years 1998-1999 and 2002-2007 (Data source: IG Pescas, Azorean Government, and Capitania de Ponta Delgada cited in Diogo and Pereira, 2013a).

Diogo and Pereira (2013b) studied impacts of recreational boat fishing on demersal fish species off Faial and Pico islands in the Azores archipelago. A roving creel survey methodology was used to collect information from recreational anglers from 2004-2005 (N = 87 anglers; 46 boats; 11% refusal rate). No island grouper catch was reported in this survey, and only 3 dusky grouper (*E. marginatus*) were reported. The most abundant species reported in the catch in terms of landings weight and number (24.6 % and 45.9%, respectively) was the blacktail comber (*Serranus atricauda*). The overall estimate of annual landings weight (all species) by the recreational boat fishery on these two islands was 163 t. This represents about 40% of the landing weight from the artisanal fishery in these areas, and is more than three times the estimated landings by shore-based recreational anglers (~ 51 t). These estimates suggest that the impact of the recreational boat fishery on demersal fish communities on these islands may be substantial. The absence of island grouper in recreational fishing surveys is consistent with UVC studies indicating the rareness of this species in the Azores (Harmelin-Vivien et al., 2001; Bertoincini et al., 2010).

Madeira Island

Fishing has a long tradition in the Madeira Islands and has been an important factor in the success of human colonization in this region (Mendes et al., 2000 cited in Ribeiro, 2008). However, in the past few decades or so, the Madeira fishing fleet has been considerably reduced in size, particularly the small boat sector (Martin, 2008). In 2008 there were 468 registered fishing vessels and 502 commercial fishing licenses sold (Martin, 2008; Morato, 2012). There is very limited information in the literature on the Madeira Islands artisanal fishery for demersal species. Demersal species are targeted mainly by small vessels (< 10 m) using bottom longlines and handlines (BLL/HL). The BLL/HL fishery for demersal species accounts for a small fraction of the total landings in Madeira (Figure 16). The demersal species fishery in Madeira is also less developed and produces significantly fewer landings (33 t in 2010) compared to the demersal species fishery in the Azores (nearly 4,000 t in 2010).

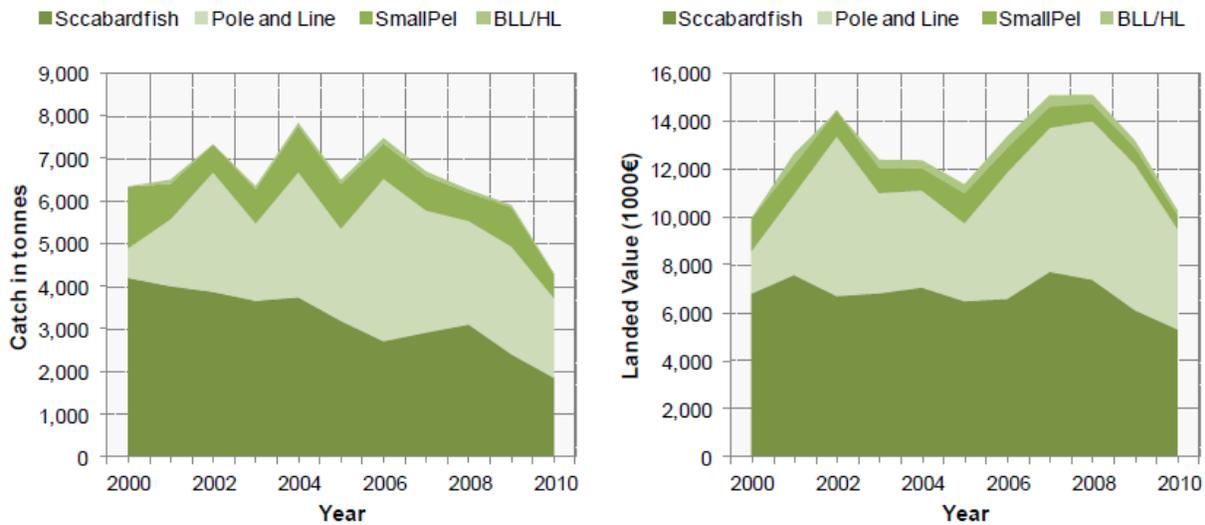


Figure 16. Annual landings (left) and landed value (right) of major fisheries components in Madeira for the period 2000-2010. “Pole and Line” is for tuna, “BLL/HL” is bottom longline and handline, and “SmallPel” is small pelagic fisheries using surrounding nets (from Morato, 2012).

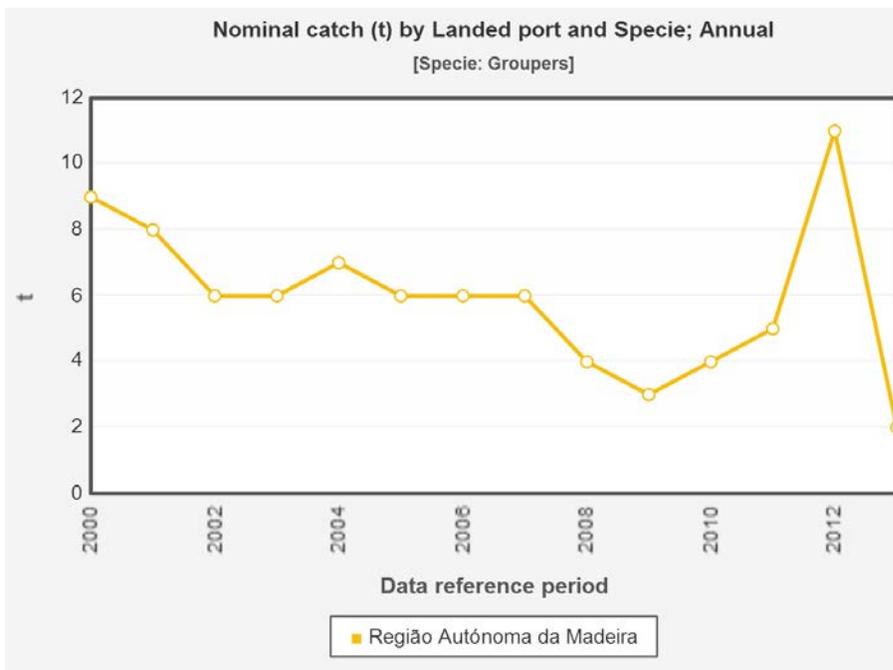


Figure 17. Madeira landings (metric tons) of groupers combined from 2002-2013 (Source: National Institute of Statistics of Portugal website²).

The Portugal National Institute of Statistics (INE) produces annual Fishery Statistics reports that include species level landings data for Madeira. As with the Azores above, I assume that INE landings in Madeira reported as ‘badejo’ refer to the island grouper. Reported landings of island

² Source - <http://www.ine.pt/>

grouper for Madeira range from 0-1 t for all years from 2000-2013 (INE, 2015). Annual commercial landings of “groupers” combined for Madeira range from 2 t to 11 t over the period 2000 to 2012 (Figure 17). The combined grouper category includes species of the genera *Epinephelus* and *Mycteroperca*.

Ribeiro (2008) found higher density and larger mean size of island grouper within the protected Garajau Marine Reserve (GMR) on Madeira Island compared to nearby unprotected areas with similar habitat types. She attributed these differences to the regulations prohibiting all fishing in the GMR. Before it was designated a marine reserve, the GMR area was subjected to heavy fishing pressure from amateur fishers using explosives, gill nets, and spears (Ribeiro, 2008).

Canary Islands

Fishing activities represent a fundamental part of the identity of the Canary Islands and many municipalities are highly dependent on this sector (Popescu and Ortega-Gras, 2013). The nearshore demersal fishery in the Canary Islands is artisanal consisting primarily of small boats (Saavedra, 2011). In recent decades, the Canary Islands artisanal fishery has experienced a significant reduction in the number of fishing vessels from an estimated 1,493 in 1986 to 818 in 2013 (Popescu and Ortega-Gras, 2013; Castro, 2014). While the number of vessels has decreased over time, vessel size and efficiency have increased with the use of more powerful engines and non-traditional equipment such as sonar and GPS (Sangril et al., 2013b). Despite the reduction in fleet size, overall fishing capacity (3,556 t in 1986 versus 5,719 t in 2012) and investment in commercial fisheries infrastructure have increased in the Canary Islands in the past thirty years, thus putting more pressure on demersal fish populations (Castro, 2014).

During periods of migratory tuna runs (typically late spring and fall) much of the benthic-demersal artisanal fishing effort shifts to tuna fishing. Significant declines in populations of tunas and other pelagics since the 1970's have contributed to the increased pressure on coastal demersal species (Moreno-Herrero, 2011). In addition, in the 1980's the Moroccan government restricted European Union vessel access to the Canary-Saharan Bank fishing grounds, resulting in a shift in fishing effort by the Canary artisanal fleet to coastal species (Pascual-Fernandez and Diaz, 1991 cited in Moreno-Herrero, 2011). While landings volume of benthic-demersal species are still relatively small compared to coastal pelagics or migratory pelagics, these resources often have high economic value (i.e., price per pound) as well as cultural value. For example, in 2011 demersal fish species accounted for 16.7% of the total fishery landings weight but 33.2% of the landing value in the Canary Islands archipelago (Popescu and Ortega-Gras, 2013).

Fishing methods used to catch demersal species include hook and line, fish traps, trammel nets, and gillnets (Bustos et al., 2009). Fish traps are used throughout the Canary Islands archipelago except for El Hierro and the Chinijo islands where they are banned (Bustos, 2008). On Gran Canaria fish traps are the primary gear used year-round by artisanal fishermen targeting demersal species. A 2009 survey of fishing effort around the island of La Palma estimated that 240 traps were being used, many of which were in operation 24 hours a day and 365 days a year within areas of the island protected from strong wave action (Sangil et al., 2013a).

Artisanal fishing for demersal species occurs throughout the archipelago but fishing pressure varies considerably between islands (Table 2). Relative fishing pressure is highest on the most

densely populated islands (Gran Canaria and Tenerife), moderately high on four islands (Lanzarote, Fuerteventura, Gomera, and La Palma), and lowest on the two least developed islands (El Hierro and Chinijo islands). Based on 2011 data, the islands with the largest volume (i.e., weight) of demersal species landings are, in order, Gran Canaria (45.9%), Tenerife (21.4%), and Fuerteventura (16%) (Popescu and Ortega-Gras, 2013).

Table 2. Number of fishing vessels and human population size per coastal perimeter on each major island within the Canarian Archipelago (from Tuya et al., 2006b).

Islands	Number of fishing ships (official) ^a	Number of fishing ships (observed) ^b	Number of ships per coastal perimeter (No. km ⁻¹) (observed ships in brackets)	Main gear types	Human population (No. of islanders per coastal perimeter, No. ind km ⁻¹) (No. of tourists km ⁻¹ y ⁻¹ in brackets)	% Of coastal perimeter with some form of fishery regulation ^c (e.g. traps are not allowed)
Highly fished (>0.5 ships per km of island perimeter)/no management						
Gran Canaria	375	240	1.54 (0.98)	Hook-and-line, traps	3251.31 (11934.15)	0
Tenerife	265	272	0.74 (0.76)	Hook-and-line, traps	2234.32 (9776.53)	0
Moderate-to-highly fished (0.15–0.5 ships per km of island perimeter)/no management						
Lanzarote	52	95	0.21 (0.38)	Hook-and-line, traps	463.51 (7487.17)	0
Fuerteventura	51	523	0.15 (1.53)	Hook-and-line, traps	220.65 (4161.02)	0
Gomera	23	78	0.23 (0.79)	Hook-and-line, traps	200.92 (2052.33)	0
Moderate-to-highly fished (0.15–0.5 ships per km of island perimeter/little management (<8%)						
La Palma	36	110	0.23 (0.70)	Hook-and-line, traps	550.5 (784.31)	7
Lightly-to-moderate fished (<0.15 ships per km of island perimeter/moderate management (>8%)						
El Hierro	15	59	0.14 (0.55)	Hook-and-line,	96.32 (284.36)	9
Chinijo	8	100	0.15 (1.02)	Hook-and-line	11.26 (178.57)	100

Fishery characteristics and existing management regulations (as % of coastal perimeter with some form of fishery regulations) are also shown.

a Canarian Government.
b Bas et al. (1995).
c National Spanish network of Marine Protected Areas (www.mapya.es/rmarinas/).

Time series data for the Canary Islands demersal fishery are very limited. Landings data prior to 2006 are only available from one port (Puerto de Mogan on Gran Canaria), and effort data are not available at all. In 2006, the government of the Canary Islands passed a rule requiring that landings be recorded at point of sale to a fish dealer (Saavedra, 2011). Historical landings data for species that account for a relatively small proportion of the catch (e.g., island grouper), are particularly scarce as catches of more rare species are often collapsed into a general category (e.g., “groupers” or “other fish”).

Saavedra (2011) compiled a database of demersal fishery landings from Puerto de Mogan, Gran Canaria for the years 1989-2011. The porgy family Sparidae accounted for 68% of total landings weight, followed by cephalopods (12%), red mullet (8%), and parrotfish (2%). Saavedra (2011) also reported landings data for the seven most important species landed from 2006-2011 at six major fishing ports on Gran Canaria. No catch information was provided for island grouper in this study, suggesting that this species is a rare catch that accounts for a very small proportion of the total demersal fishery landings on Gran Canaria. Solari et al. (2003) reported landings of island grouper in the multi-species trap fishery from Puerto de Mogan for the period 1989-1999. Average monthly landings of island grouper was 46 fish, based on 45 months (out 120 months) for which data were available. Detailed monthly data were not available to assess trends in island grouper landings over time. Although island grouper accounted for only about 2.3 percent of the total catch in numbers of fish over this time period, given their relatively large size it is

likely that the proportional contribution of island grouper to the landings weight in the Gran Canaria trap fishery is considerably greater. A comparison of data compiled by Saavedra (2011) and Solari et al. (2003) for Puerto de Mogan suggests that the island grouper may be an important component of the artisanal trap fishery on Gran Canaria but is less important for fisheries using other gears to capture demersal species (e.g., hook and line, gillnets, spear guns).

Island grouper are considered an important component of the small artisanal fishery on El Hierro, where fish traps are banned and demersal species are mainly caught with hook-and-line gears (Falcón et al., 2007a). Falcón et al. (2007c) compared demersal species landings on El Hierro Island in the period before and after implementation of the La Restinga Marine Reserve. From 1990-1995 (before implementation) a total of 700 island grouper were landed (116.7 fish per year). From 1997-2005 (after implementation) a total of 1,239 island grouper were landed (137.7 fish per year). Over the entire period (1990-2005), island grouper were the 9th most abundant species landed in numbers of fish.

Recreational fishing pressure has increased in the Canary Islands in the past few decades as a direct result of human population growth and a growing tourism sector (Sangil et al., 2013b). The number of recreational fishing licenses sold throughout the archipelago more than doubled from 2005 (~ 48,000) to 2011 (~ 116,000) (Castro, 2014). The majority of recreational anglers are from the two most populous islands of Tenerife (39%) and Gran Canaria (35%). In 2011 there were an estimated 3,388 recreational fishing boats on Gran Canaria - with a coastline of 242 km this equates to a density of about 14 recreational fishing boats per km of coastline (Morales-Malla, 2011). Sangil et al. (2013a) estimated there were 5,000 recreational fishing participants and 700 recreational fishing boats on the island of La Palma in 2009. There are also indications that Spain's economic crisis and growing unemployment have resulted in increased levels of subsistence fishing and poaching in the Canary Islands (Moreno-Herrero, 2011). Recreational fishery landings data are lacking as there are no monitoring programs for this fishery sector in the Canary Islands. Jimenez-Alvarado (2010, cited in Saavedra, 2011) estimated total recreational fishery landings based on license sales by fishing mode, number of recreational fishing vessels, and limited recreational catch and effort survey data. Results suggest that recreational fisheries have a significant impact on fish populations, and on three islands (Gran Canaria, Gomera, and Fuerteventura) recreational landings of benthic-demersal species likely exceed artisanal fishery landings. Although species level recreational landings data are not available, this study indicates that the Canary Islands recreational fishery, which is focused on demersal fish species, likely has an impact on island grouper abundance.

Without basic fisheries time series data (e.g., catch, effort, sizes, and gears) it is difficult to assess or quantify the impact of artisanal and recreational fishing on marine ecosystems in the Canary Islands, let alone the impact on a relatively rare species such as the island grouper. A few studies have demonstrated the negative impact of fishing by correlating relative fishing pressure with target species abundance at different locations throughout the archipelago. Tuya et al. (2006a) studied the relationship between human pressures (i.e., population density and fishing pressure) and abundance of four serranid species on the major islands of the Canary Islands archipelago. Island grouper mean density and mean biomass were significantly higher on islands with the lowest fishing pressure and lowest population density (El Hierro and Chinijo islands) compared to other islands within the archipelago (see Figure 9 above in "Abundance and

Population Structure” section). Similar results were found for the dusky grouper, suggesting that human intervention in the Canaries has negatively impacted abundance of these large, slow growing species with low population turnover rates. The effects of fishing pressure on the two comber species (*S. scriba* and *S. atricauda*) in this study were less noticeable. Compared to the groupers, the comber species are smaller, faster growing, intrinsically less vulnerable to fishing, and of lower commercial interest (Tuya et al., 2006a; Diogo and Pereira, 2013a; Froese and Pauly, 2014).

Tuya et al. (2006b) compared island grouper mean densities on El Hierro and the Chinijo islands across sites with varying levels of protection from fishing: RI = no-take zone; ZA = reserve buffer zone with only recreational fishing allowed for grouper species; AV = outside reserve with recreational and commercial fishing permitted, except fish traps which are banned throughout these islands (Figure 18). Mean densities were, in general, very small around the Chinijo islands compared to those found around El Hierro. The authors attributed this “island effect” to differences in artisanal and recreational fishing pressure (Chinijo > El Hierro) and inadequate enforcement within the La Graciosa reserve. The “reserve effect” (i.e., higher abundance within than outside reserve boundary) was not evident for island grouper within the El Hierro Restinga reserve: i.e., no statistically significant differences were found in mean density between the no-take zone, the buffer zone, and the fishing area outside the reserve. The fact that fish traps are entirely banned on El Hierro (both within and outside the reserve) may minimize the “reserve effect” around this island. Tuya et al. (2006a) found significantly higher island grouper mean densities on El Hierro compared to other islands within the archipelago which still allow fish traps. Mean density of island grouper was statistically larger within the Chinijo islands La Graciosa reserve (RI and ZA) than neighboring sites outside the reserve (AV). Bustos (2008) also compared mean density of island grouper across sites with varying levels of protection from fishing within and nearby the La Graciosa marine reserve. Similar to Tuya, she found a significant positive correlation between island grouper mean density and level of protection (i.e., higher density with protection), and no island grouper were observed in areas sampled outside the La Graciosa reserve boundary.

Sangil et al. (2013a) studied the relationship between fishing pressure and conservation status at sites around La Palma Island using Principle Component Analysis (PCA) and Geographic Information Systems (GIS). The following biological parameters were used as indicators of conservation status: percentage cover of seaweeds; mean density of the sea urchin *Diadema africanum*; mean biomass of sea urchin predators (*Diplodus cervinus*, *Diplodus sargus*, *Balistes capriscus*, *Bodianus scrofa*, *Canthidermis sufflamen*, *Chilomycterus atringa*); mean biomass of combined grouper species (*E. marginatus*, *M. fusca*, *Serranus atricauda*); and mean biomass of *Sparisoma cretense*. Data were collected in 2009 using a UVC point-count method at 51 sites (9 transects per site) around La Palma island (Figure 19). The first axis of the PCA, which explained 47.2% of the variation, displayed a gradient of conservation status from ecologically healthy sites with abundant seaweed and fish (positive axis values) to disturbed sites with higher *D. africanum* densities and lower seaweed cover and fish biomass (negative axis values). Fishing effort data were collected from boat-based and shore-based surveys conducted twice per month for one full year at fishing access sites around the island. Effort data included number and location of deployed fish traps, active fishing boats (commercial and recreational), shore based fishermen, and spearfishermen.

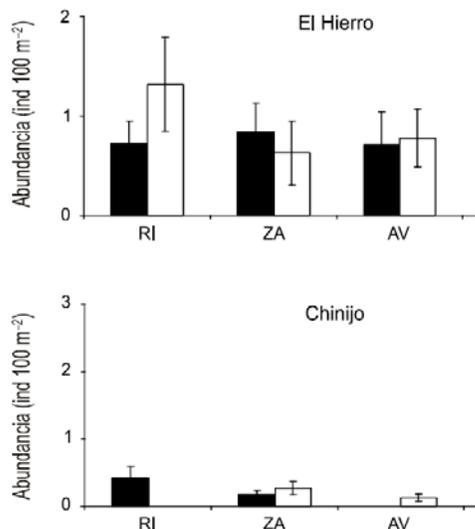


Figure 18. Mean density (\pm SE) of island grouper recorded from 2003-2004 at two localities (black and white bars) sampled in different fishing management categories within and nearby the La Restinga (El Hierro island) and La Graciosa (Chinijo islands) marine reserves: RI = no-take zone; ZA = reserve buffer zone - only recreational fishing allowed; AV = outside reserve – commercial and recreational fishing permitted, except fish traps (from Tuya et al., 2006b).

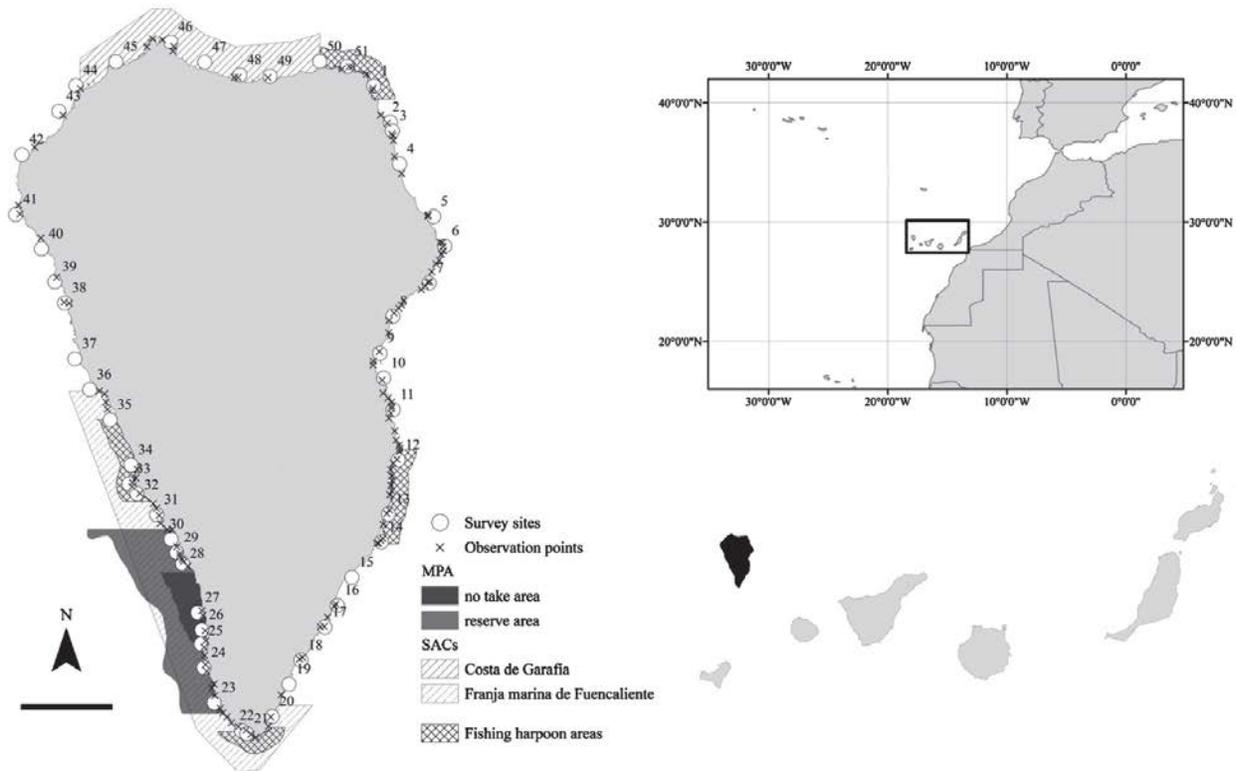


Figure 19. La Palma Island (Canary Islands archipelago), showing the location of the MPA, no-take zone, SACs, and designated harpoon fishing areas (from Sangil et al., 2013a).

The correlation between fishing pressure and each biological parameter, including grouper biomass, was high and negative. The sampled locations with the highest combined grouper mean biomass corresponded with areas of lowest fishing pressure inside the La Palma MPA, particularly within the no-take portion where all fishing activity is prohibited (Figure 20). The overall mean grouper biomass across all sites was 303.1 g/100 m², compared to 569.9 g/100 m² within the limited fishing MPA area, and 2,401.5 g/100 m² within the no-take area. While fishing pressure was also low in the north and northwest, grouper biomass in this part of the island was not nearly as high as within the MPA. Groupers were virtually absent from the heavily fished areas just to the north of the MPA and on the eastern side of the island. Although this study did not provide mean biomass data for groupers at the species level, based on Sangil et al. (2013b) island grouper accounted for approximately one-third of the total biomass of the three grouper species combined.

Sangil et al. (2013b) reported a statistically significant negative correlation between island grouper biomass and each of the following measures of fishing effort around La Palma: number of fish traps; number of harpoon fishermen; distance from nearest main fishing harbor; and total number of fishing boats (Spearman's correlation coefficient $p < 0.01$). Island grouper biomass was not significantly correlated with the number of shore fishermen, suggesting that this fishing mode has less of an impact on this species than boat fishing, spearfishing or the use of traps.

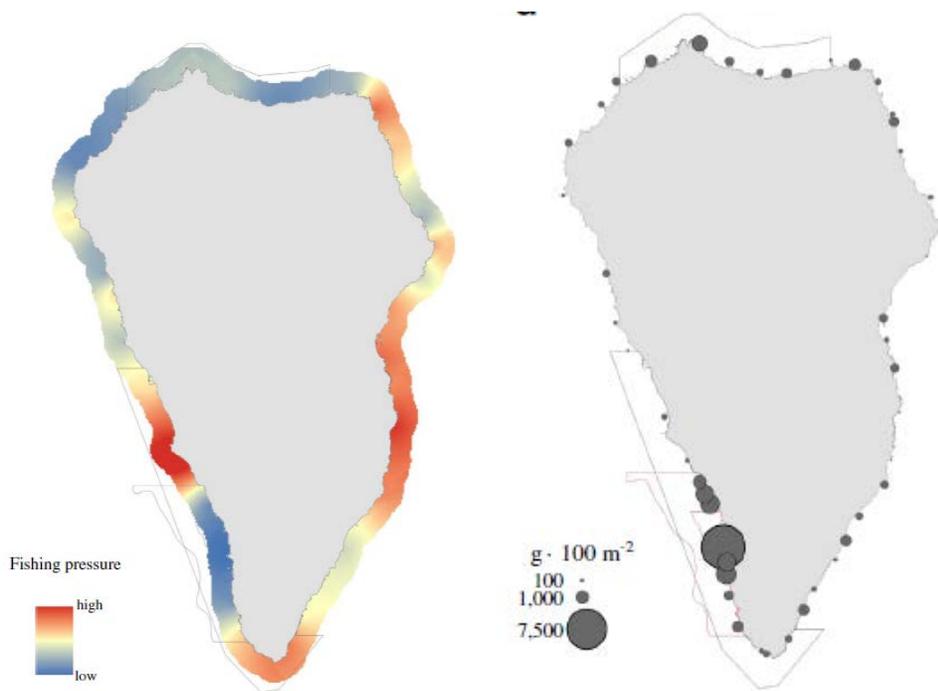


Figure 20. Model of La Palma (Canary Islands) relative fishing pressure (left map), and mean biomass (g/100 m²; right map) of groupers combined (*E. marginatus*, *M. fusca*, and *S. atricauda*) (from Sangil et al., 2013a).

Cape Verde

The fisheries sector in Cape Verde represents less than 1% of the gross domestic product (GDP) but still plays an important role in local diets, as a source of income through exports, and for cultural purposes (Trindade-Santos et al., 2013; Fidalga et al., 2014; Cape Verde Chamber of Commerce, Industry, and Tourism website³). Artisanal fishing in Cape Verde is mainly coastal (within 10 km from shore) and small scale, practiced with hand lines from open wooden boats typically from 3 m to 6 m with small outboard engines (Medina et al., 2007). There are approximately 3,400 artisanal fishermen, 1,000 vessels, and 85 fishing ports distributed throughout the Cape Verde archipelago (Medina et al., 2007; PRAO – CV, 2012). The Cape Verde artisanal fishery typically lands between 4,000 t and 5,000 t of fish annually, of which about 1,000 t are demersal species (PRAO – CV, 2012). Basic fisheries data such as catch and effort are limited in Cape Verde, particularly for the demersal species fishery. Since 1992, the Cape Verde National Institute for Fisheries Development (INDP) has compiled data on fishing catch and effort for the more important artisanal fishery target species (Medina et al., 2007). However, as a small component of the total catch, island grouper are not one of the species monitored or reported in INDP official statistics (Albertino Martins, personal communication).

Veiga (2007) collected landings data from the artisanal fishery of Santa Cruz on the island of Santiago from January through May 2007. Landings were dominated by small pelagics (particularly mackerel scad), and only 1.0 kg of island grouper landings were reported. A recent assessment of mackerel scad (*Decapterus macarellus*), bigeye scad (*Selar crumenophthalmus*) and black spot picarel (*Spicara melanurus*) indicates that stocks of commercially important small pelagics are either fully exploited or overexploited in Cape Verde (DeAlteris, 2012). Continued overfishing of these stocks could result in added fishing pressure on demersal species.

The recreational fishery in Cape Verde lacks monitoring and I could not find any information on this sector. Subsistence catches in Cape Verde have shown an increasing trend in recent years, suggesting increased dependence on fish as a source of food, and possibly related to declines in agricultural production due to climate change induced droughts (Trindade-Santos et al., 2013).

Summary: Threat of Overutilization from Fishing

Within the island grouper's range, nearshore fishing pressure on demersal species is highly variable: relatively high in densely populated areas or areas with well-developed demersal fisheries (e.g., Gran Canaria and Tenerife in Canary Islands; São Miguel in the Azores); relatively low in areas where demersal resources are significantly less abundant and not an important component of total fisheries landing (e.g., Madeira), and in less densely populated areas (e.g. El Hierro). The relative contribution of island grouper to total commercial and artisanal landings volume of fisheries operating throughout the species' range has been very minor in recent years. Official landings data from the Portugal National Institute of Statistics indicate that commercial fisheries in the Azores and Madeira archipelagos each land less than 1 t of island grouper per year. Island grouper may still be considered an important component of particular fisheries in the Canary Islands (e.g., Gran Canaria trap fishery and El Hierro hook-and-line fishery), although these fisheries are relatively small and target many demersal species at

³ Source - <http://www.portugalcaboverde.com/main.php>

once. The small contribution of island grouper to fisheries landings is consistent with the abundance information suggesting this species is very rare throughout much of its limited range. Although recent landings are very small, there is no before-impact baseline data prior to the period of relatively high fishing pressure to compare with recent landings. Bustos (2008) estimated total landing of island grouper decreased by approximately 95% over the last fifty years on the island of Gran Canaria due to heavy fishing pressure, although data to support this estimated decline were not available.

Several studies indicate that island grouper are found in higher abundance in areas where fishing activities are either prohibited (i.e. “no-take”) or limited with gear or sector restrictions, or in unpopulous areas where relative fishing intensity is generally low (Tuya et al 2006a; Bustos, 2008; Ribeiro, 2008; Sangil et al., 2013a; Sangil et al., 2013b). Biomass of island grouper is significantly higher around islands where trap fishing has been banned (i.e., El Hierro, Chinijo, and within the La Palma MPA) compared to other Canary islands, and highest within no-take reserves where all fishing is banned. Combined with the high vulnerability of this species, these results suggest that fishing overexploitation has contributed to the very low abundance of island grouper observed in many areas. This conclusion is based on correlational studies, some of which do not fully address the role of other factors (e.g., habitat structure and availability, variable recruitment and settlement, and competition) on the observed patterns of island grouper distribution and abundance. Variability in factors influencing the natural distribution and abundance of island grouper may be quite large between different archipelagos or even individual islands within an archipelago. One would expect less variability across different sites within a particular island. To control for habitat variability, Sangil et al. (2013a) only sampled rocky reef sites around a single island (La Palma) within a limited depth range (5-20 m). Large differences in grouper biomass observed at adjacent sites, straddling two sides of the MPA boundary, provide the strongest indication that fishing pressure is the underlying causal factor. Similarly, Tuya et al. (2006a) attempted to minimize the effect of habitat type on the distribution and patchiness of fish assemblages by only sampling rocky-bottoms with similar slopes and depths. Despite the caveats and limitations of correlational studies, the cumulative research strongly suggests that artisanal fisheries overexploitation has negatively impacted island grouper abundance in the Canary Islands, and some heavily fished areas have likely experienced a sharp decline. The rapidly expanding recreational fishery sector (Castro, 2014) has also contributed to the decline in island grouper abundance, and on some Canary Islands recreational landings may already exceed artisanal fishery landings (Saavedra, 2011).

Limited landings size data also suggest a high level of fishery exploitation for this species. Bustos et al. (2009) found very few island grouper greater than ten years old in commercial catches from Gran Canaria and Fuerteventura between January 2004 and December 2005. Diogo and Pereira (2013a) reported a mean length of island grouper caught by recreational spearfishermen in the Azores of 38 cm. This mean length represents fish in the 4 to 6 year-old range, and is only slightly larger than female age at maturity. These data suggest that, at least in some parts of its range, the island grouper is experiencing a very high rate of fishing mortality. This is particularly concerning for a species with a limited range that is highly vulnerable to the effects of overfishing due to certain life history and behavioral traits.

Aquarium Trade

Calado (2006) identified the island grouper as one of 172 species (63 fish species) in Portuguese waters that could be a potential target for the marine aquarium industry. However, there is no information indicating that island grouper are currently being sold for aquariums or that this form of exploitation is a current threat to the species.

Disease, Predation, and Competition

The escape of marine aquaculture fish species represents a potential threat to the island grouper (Toledo-Guedes et al., 2014). Negative consequences from releases of non-native (exotic) species can include predation on native species, competition for resources, and introduction of parasites and diseases. European sea bass (*Dicentrarchus labrax*) are legally cultured in the Canary Islands of La Palma, Tenerife, Gran Canaria, and Lanzarote (Toledo-Guedes et al., 2009). Total production of marine finfish in open-net cages increased in the Canary Islands from 1,685 t in 2001 to 7,900 t in 2009 (APROMAR, 2012). A massive escape event occurred at an aquaculture operation on La Palma between December 2009 and January 2010 resulting in the accidental release of 1.5 million fish (90% sea bass and 10% sea bream) into the wild (Toledo-Guedes et al., 2014). UVC sampling at sites within 30 km of the release point, before and after the event, indicated a significant increase in mean trophic level as a result of the high trophic level of escaped fish. Within the protected La Palma MPA, where fish assemblages are supposed to be best preserved, biomass of non-native sea bass was larger than the rest of the medium to high trophic level species combined after the escape event took place (Toledo-Guedes et al., 2014).

Toledo-Guedes et al. (2012) found evidence of gonadal maturation occurring in the wild in escaped male and female European sea bass on Tenerife island in 2009. This study suggests that non-native sea bass have found suitable habitat for maturation, although it does not confirm fertilization success, larval survivorship, or post larval recruitment into the wild. The authors postulate that the combination of suitable biotic and non-biotic conditions, high frequency of escape events (Toledo-Guedes et al., 2009), and overutilization of native fish assemblages (Tuya et al., 2006a), could facilitate establishment of self-reproducing non-native sea bass populations in the Canary Islands.

As an opportunistic, high trophic level, piscivorous species, non-native European sea bass could be competing with native species such as the island grouper (Toledo-Guedes et al., 2009). However, studies indicating that aquaculture escape events have resulted in a decline in island grouper abundance are lacking. Toledo-Guedes et al. (2014) reported island grouper were very rare in areas affected by the escape event both before and after the event occurred based on UVC sampling conducted from 1 m to 5 m depths. Sangil et al. (2013b) collected data on island grouper mean biomass from 2008-2009 at 51 sites around La Palma, including several sites within the area affected by the escape event. However, all sampling was conducted prior to the escape event and there is no information available to adequately assess the impact of escaped European sea bass on island grouper fitness or survival.

In addition to competition for habitat and food, European sea bass may be spreading parasites to native fish species. Toledo-Guedes et al. (2012) found the presence of the Myxosporean parasite

Sphaerospora testicularis in aquaculture escaped sea bass on Tenerife island. The pathology of *S. testicularis* includes the destruction of both testicular germinal cells and Sertoli cells, potentially leading to parasitic castration (depending on the exact location and intensity of infection) as these cells are crucial for spermatogenesis (Toledo-Guedes et al., 2012). While the possible spread and transmission of this parasite threatens the fitness and reproductive potential of native fish species, there are no studies indicating that this has occurred.

The introduction of invasive species through ship ballast water is also a potential threat to the island grouper. Approximately 30,000 commercial vessels enter Canarian harbors each year, mostly in Gran Canaria and Tenerife (ISTAC, 2013 cited in Riera et al., 2014). The African hind (*Cephalopholis taeniops*) is an invasive species from Guinea (West Africa) that is thought to have arrived to the Canary Islands in ballast water (Riera et al., 2014). Stable populations of this predatory fish may have already established in the port cities of Las Palmas and Santa Cruz (Riera et al., 2014). However, as with the European sea bass, there are no studies indicating that the invasive African hind has negatively impacted native fish populations.

Other Natural or Manmade Factors

I did not find information on any other natural or manmade factors that could potentially pose an extinction risk for the island grouper.

Inadequacy of Existing Regulatory Mechanisms

Below is a description of existing regulatory mechanisms relevant to the island grouper within each archipelago, and an evaluation of their adequacy in addressing threats to the species' survival.

Azores

The Azores regional government has had legislative and management authority over its coastal marine resources since becoming an autonomous region of Portugal in 1976. Fisheries management in the Azores has evolved primarily through political pressures exerted by local fishing communities to legislate and implement local regulations (Pham et al., 2013). While commercial and recreational minimum size limits and bag limits are in place for some species, there are no specific regulations for island grouper in the Azores. Bottom longlines, first introduced in the Azores in the 1980's, were banned within three miles from shore in 2000 to protect populations of heavily exploited nearshore demersal species (Morato, 2012). New regulations were implemented for recreational boat fishing in 2008 including daily bag limits, gear restrictions, and a fishing license requirement (Diogo and Pereira, 2013b). Compliance with the new recreational boat fishing regulations has been relatively good on the islands of Faial and Pico (Diogo and Pereira, 2013b). Diogo and Pereira (2013b) estimated that recreational bag limits have resulted in a 22% decrease in demersal fish species landings.

The use of SCUBA equipment for spearfishing has been banned throughout Portugal, including its autonomous regions, since the 1960s (Diogo and Pereira, 2013a). Additional spearfishing regulations were established in the Azores in 1985 including a five-specimen daily bag limit (more recently raised to 10 specimens) and the requirement of a spearfishing license (Diogo,

2007). The only fish species explicitly protected from spearfishing (both in the Azores and Madeira) is the dusky grouper, the catch of which is permitted by other fishing methods (Diogo and Pereira, 2013a). Diogo and Pereira (2013a) reported that spearfishermen on the island of São Miguel exceeded the daily bag limit of 10 fish on 37.0% of trips sampled, and illegally captured dusky grouper on eight occasions (3.6% of trips sampled).

Several coastal MPAs are designated in the Azores, including the “Island Natural Parks” of each of the nine main islands in the archipelago (Morato, 2012; Schmiing et al., 2014a). In 2008, the Azores regional government established the Corvo Island Natural Park, which includes a 25,739 ha MPA (Abecasis et al., 2013). Restrictions within the Corvo MPA include a ban on longline fishing, trawling, deepwater gill netting, and vessels over 10 m in length. Currently there are no fishing restrictions on the small vessel handline fishery and there is no management plan in place for this MPA (Abecasis et al., 2013). New MPAs were also implemented in 2008 around the islands of Faial and Pico. The combined area of these MPAs within the 200 m depth margin is 314 km², which represents 42.4% of the total marine area to 200 m depth surrounding these two islands (Diogo and Pereira, 2013b).

Although MPAs cover a large proportion of the Azores coastal zone, areas fully protected from fishing (i.e., ‘no take’ zones) are extremely small. Commercial and recreational fishing regulations within the Azores coastal MPAs are considered inadequate to protect vulnerable species and ecosystems (Diogo and Pereira, 2013b) and several established MPAs are still lacking a management plan (Schmiing et al., 2014b). The Caldeirinhas Nature Reserve on Faial Island, which occupies only 10 ha, was established as a no-take reserve in 1988 (Schmiing et al., 2014a). Schmiing et al. (2014a) did not find evidence of a “reserve effect” within Caldeirinhas, possibly due to mismanagement, lack of enforcement, or the very small spatial scale. A community-driven no-take reserve was established by local residents in 1999 on the small island of Corvo. The Caneiro dos Mero (“Grouper’s Alley”) reserve was organized by a local dive tour operator in an effort to protect an area with high abundance of large dusky grouper (Abecasis et al., 2013). The prohibition on fishing within Caneiro dos Mero is recognized and widely accepted within Corvo, even though there remains no legal foundation for its existence (Abecasis et al., 2013). According to Abecasis et al. (2013), Caneiro dos Mero represents one of the few no-take MPAs in the Azores with high compliance. Small no-take areas have recently been established by the regional government to protect four popular dive sites on the island of Santa Maria (Abecasis et al., 2013).

Madeira

Similar to the Azores, the Madeira regional government has authority over coastal marine resource legislation and management since becoming an autonomous region of Portugal in 1976. Commercial fishing regulations in Madeira are primarily aimed at controlling the major fisheries for tunas and small pelagics. The small demersal fishery, which contributes less than 1% of the total landings, is largely unregulated. The use of gill nets has been discouraged in Madeira and in recent decades no licenses have been issued by the regional fisheries department for this fishing gear (Ribeiro, 2008). Traditional fisheries regulations (e.g., size limits, bag limits, catch quotas, and seasonal closures) for restricting catch and effort do not exist for island grouper in Madeira.

There are currently five MPAs in the Madeira archipelago, two of which (Desertas Natural reserve and Selvagens Islands reserve) are located around remote, uninhabited islands (Morato, 2012). The 3.8 km² Garajau Marine Reserve (GMR) is the only no-take MPA located on the main island of Madeira. The GMR was established in 1986 in an effort to control progressive overfishing of the very limited shallow coastal habitats surrounding Madeira Island, and to act as a source of recruitment to fished habitats in bordering areas. Activities prohibited in the GMR include all fishing (commercial, recreational, and spearfishing), use of motor boats (except to approach beaches), capture of animals or marine plants, and extraction of sand or other materials (except for scientific research with a permit) (Ribeiro, 2008). However, enforcement of these rules is lacking and cases of poaching within the GMR are often reported by reserve rangers - much of this illegal activity occurs at night when enforcement is not present (Ribeiro 2008). Despite insufficient enforcement, there are indications that the GMR has been effective in increasing abundance of groupers within the reserve boundaries. Ribeiro (2008) found higher density and larger mean size of island grouper within the GMR compared to nearby similar habitats. The dusky grouper was exclusively recorded inside the reserve area, but with very low frequency and abundance. Reserva Natural do Sítio da Rocha do Navio is a 3.1 km² MPA located on the north coast of Madeira island. This MPA is managed as a multi-use area where commercial and recreational fishing are allowed but specific gears (i.e., gill nets and spearfishing) are prohibited.

Canary Islands

The Canary Islands regional government has authority over coastal marine resource legislation and management since officially becoming an autonomous community of Spain in 1982 (Popescu and Ortega-Gras, 2013). In 2003 the regional government passed the Canary Islands Fisheries Act in an effort to control overexploitation of fisheries resources. However, there are still relatively few restrictions on catch and effort for demersal species in the Canary Islands. In general, commercial fishermen in the Canary Islands are reluctant to accept measures involving the reduction of fishing effort or restricted access to certain fishing grounds (Couce, 2010 cited in Moreno-Herrero, 2011).

Fish traps are banned on El Hierro and the Chinijo islands but remain an important artisanal fishing gear for demersal species elsewhere throughout the Canary archipelago. There are currently no daily catch limits or annual quotas for island grouper. The only regulation specific to island grouper is a 350 mm minimum size limit which went into effect in 1995 (Bustos et al., 2009). The minimum size allowed is slightly larger than the estimated female length at maturity (L₅₀ = 335 mm), and therefore may have limited benefit for protecting the spawning population of island grouper. In a sample of island grouper commercial landings (Gran Canaria and Fuerteventura islands, 2004-2005), 18.6% were below the legal size limit, suggesting a relatively high rate of non-compliance with this regulation. Bustos et al. (2010) noted that sublegal island grouper brought to the surface from depths of more than 30 m often suffer from barotrauma and are not likely to survive when released.

The implementation of MPAs in the Canary Islands is viewed as an important conservation measure in promoting demersal species recovery (Clemente et al., 2011; Sangil et al., 2013a). Three marine reserves have been established in the Canary archipelago: La Graciosa (including

Lanzarote and Chinijo islands); La Restinga (El Hierro); and La Palma. These three reserves combined constitute approximately 0.15% of the Canarian archipelago Exclusive Economic Zone (EEZ) (Sangil et al., 2013a). All three reserves include a “no-take” zone where exploitation of marine resources is prohibited, surrounded by a “buffer zone” where certain fishing activities are allowed (Tuya et al., 2006b). La Graciosa Marine Reserve, established in 1995, covers 70,000 ha (40% in offshore waters; 60% nearshore) of which less than 2% (1,225 ha) is “no-take” (Claudet et al., 2008). The following fishing regulations apply within the 68,775 ha La Graciosa buffer zone: commercial hook and line fishing and tuna-bait seining are allowed; fish traps and spearfishing are prohibited; and recreational fishing is allowed but local residents have special recreational boat fishing privileges (Chuenpagdee et al., 2013). La Restinga marine reserve (El Hierro), established in 1996, covers 993 ha, including a 180 ha no-take zone (Claudet et al., 2008). The La Restinga buffer zone is divided into two management units: 1) a restricted use zone where only commercial hook fishing is allowed, and 2) a traditional use zone where local traditional fishing, recreational shore fishing, and SCUBA diving are allowed. The La Palma island marine reserve, established in 2001, covers 3,719 Ha including a no-take zone (Sangil et al., 2013a). In the La Palma buffer zone fish traps and recreational fishing from boats are prohibited activities while commercial fishing with hook-and-line gear and shore-based recreational fishing are allowed.

Falcón et al. (2007a; 2007b) conducted a long-term monitoring program to evaluate the response to protection of fish species inhabiting shallow rocky habitats within the La Restinga (El Hierro) and La Graciosa (Chinijo islands) marine reserves. Island grouper mean density was recorded at the same sampling locations prior to reserve establishment (in 1996 for La Restinga; 1997 for La Graciosa) and several years after implementation within three management zones: IR = no-take integral reserve; RUZ = only commercial hook fishing allowed; TUZ = traditional commercial gears, recreational shore fishing and SCUBA allowed. A declining trend in island grouper mean density was observed within the La Restinga reserve from 1997 to 2005, even within the IR no-take zone (Figure 21). The authors attributed this decline to fishing pressure on this species within the areas that allow some fishing (TUZ and RUZ), including possible poaching within the no-take reserve. No clear trend was found within La Graciosa reserve, as island grouper mean densities were highly variable and generally not statistically different across the four years sampled.

A few studies reported higher island grouper mean density (or biomass) within the La Palma and La Graciosa marine reserves compared to areas outside of these reserves (Tuya et al., 2006a; Bustos, 2008; Sangil et al., 2013a; Sangil et al., 2013b). These results suggest that marine reserves have been somewhat effective in reducing the impacts of overfishing on island grouper abundance within the reserve boundaries. The “reserve effect” on island grouper biomass was reported for both no-take zones and, to a lesser extent, the limited fishing “buffer” zones. Other studies found no evidence of a “reserve effect” within La Restinga reserve on El Hierro island (Tuya et al., 2006b; Falcón et al., 2007a; Bustos, 2008). In general, island grouper were relatively more abundant on El Hierro compared to other islands within the archipelago. The lack of a “reserve effect” on El Hierro may have been due to smaller differences in fishing pressure within and outside the La Restinga reserve boundaries compared to La Palma and La Graciosa reserves. Fishing pressure is relatively low throughout El Hierro, and the entire

nearshore coastal area is managed with fairly restrictive fishing regulations including a well-enforced ban on fish traps (Falcón et al., 2007a).

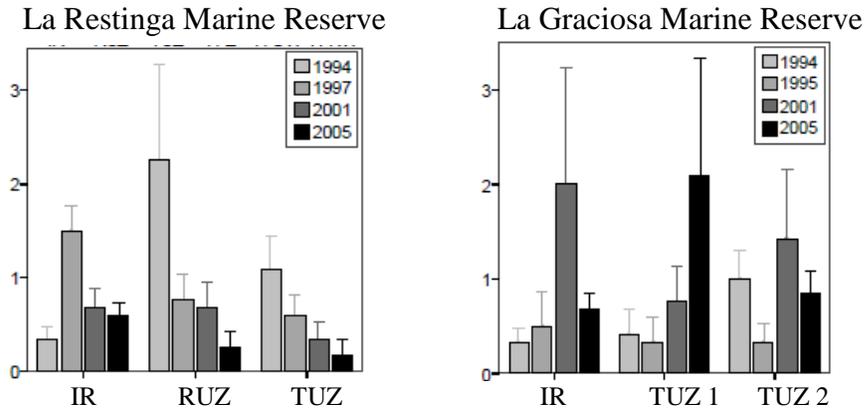


Figure 22. Mean density (\pm SE) of island grouper (fish/100 m²) recorded in years before (1994 and 1995) and after (1997, 2001, and 2005) reserve implementation in different management zones: IR = no-take integral reserve; RUZ = only commercial hook fishing allowed; TUZ = traditional commercial gears, recreational shore fishing and SCUBA allowed (from Falcón et al., 2007a; 2007b).

A new strategy of marine conservation and management in the Canary Islands promotes the establishment of Micro Areas Ecoturísticas Litorales (MAELs). These MAELs are based on a bottom-up, co-management approach where local authorities, communities, and stakeholders play an active role in establishing protected areas and promoting sustainability and ecotourism on a small spatial scale (Vidal-López et al., 2014). The MAELs typically allow a variety of non-extractive recreational activities (SCUBA, snorkeling, surfing, kayaking etc.) but prohibit commercial fishing and other extractive or industrial activities. Since 2008, MAELs have been created on the islands of Gran Canaria, Tenerife, and La Palma. Vidal-López et al. (2014) reported the presence of island grouper in two proposed MAELs on Gran Canaria (Canteras-Confital and Cabrón-Risco Verde). The MAELs could potentially reduce the threat of fishing pressure on demersal species within their boundaries, although considering their very small size, this benefit may be limited for non-sedentary species.

In addition to marine reserves and MAELs, several Special Areas of Conservation (SACs) have been established in the Canary Islands under a European Union habitat directive. However, fishing regulations and monitoring programs have not been implemented in Canary Islands SACs, and these areas have not proven effective in protecting demersal fish species from overexploitation (Sangil et al., 2013a; Espino et al., 2014; Martín-García et al., 2015).

The island grouper is not included on the Canary Islands Endangered Species List which was established in 2001 (Bustos et al., 2009). In 2010 the Canarian Parliament approved a new version of the Canarian catalogue of protected species that both reduced the number of species included and the protections afforded (Fernández-Palacios and Nascimento, 2011). Although island grouper are not a protected species, the general weakening of protected species legislation in the Canary Islands will likely impact nearshore marine habitats occupied by this species

(Fernández-Palacios and Nascimento, 2011). The island grouper is also not currently on the Canary Islands list of prohibited marine species to capture, which includes 10 fish species, 2 crustaceans, and 10 mollusks (Canary Islands Government, Ministry of Agriculture, Livestock, Fishing, and Water website⁴).

Cape Verde

The Republic of Cape Verde is a former Portuguese colony which gained independence in 1975. The Cape Verde National Institute of Fisheries Development (INDP) is responsible for monitoring and managing coastal marine resources. There is evidence that fisheries in Cape Verde are not being managed in a sustainable way as excess fishing capacity is a major and growing problem for fisheries managers (Fidalga et al., 2014). Restricting access to fishing is viewed by many as unacceptable policy, given the traditional values associated with fishing, high rate of unemployment, and the lack of sustainable alternative employment in communities throughout the archipelago (Fidalga et al., 2014). Traditional fisheries regulations (e.g., size limits, bag limits, catch quotas, and seasonal closures) for restricting catch and effort do not exist for island grouper in Cape Verde. The following fishing methods are prohibited in the Cape Verde demersal species artisanal fishery: handlines within three miles from shore; the use of dynamite and poison; and spearfishing with SCUBA gear (Palin, 2012).

Cape Verde's system of MPAs includes 27 sites which cover a total ocean area of 13,460 ha (UNDP, 2010). Since the 1990s, the small uninhabited island of Santa Luzia (34 km²), and two nearby islets (Branco and Raso), have been designated marine reserves in their entirety (Freitas, 2012). In 2003, additional MPAs were established throughout the archipelago, the majority of which were on the islands of Boavista, Sal, and Maio. Despite the large number of sites designated, MPAs in Cape Verde effectively exist only on paper and their protective status has in practice not been realized (Freitas, 2012). Santa Luzia remains the only MPA in the archipelago with an operationalized management plan. Inadequate enforcement of restrictions on artisanal fisheries (mainly from the nearby islands São Vicente and São Nicolau) within the Santa Luzia marine reserve has likely reduced the effectiveness of this MPA (Almeida et al., 2010 cited in Freitas, 2012). The artisanal fishing sector in Cape Verde has not yet faced a serious scarcity crisis, and local fishermen are generally skeptical of the "spillover effect" benefits that can result from no-take reserves (UNDP, 2010).

Summary of Existing Regulatory Mechanisms

The nearshore demersal fisheries throughout the Macaronesian islands region are not highly regulated. Although these fisheries are primarily small-scale and artisanal, the cumulative impact on fish populations can be substantial, particularly for species that are highly vulnerable to overexploitation, such as the island grouper. There are no annual catch quotas, daily bag limits, or seasonal closures in place for island grouper in any part of their range. The Canary Islands is the only archipelago with a minimum size limit for this species, and enforcement does not appear adequate to address non-compliance with this regulation. Gear restrictions (e.g., fish traps, gillnets, bottom longlines, and SCUBA) are in place for demersal fisheries in some areas

⁴ Source - <http://www2.gobiernodecanarias.org/agricultura/pesca/especies/default.htm>

and the use of explosives is widely prohibited. However, the effectiveness of gear restrictions is substantially reduced by inadequate enforcement, as well as a shift in fishing effort to other (legal) methods of capturing demersal species. There is some indication that banning fish traps has had a positive impact on island grouper abundance in the Canary islands, although this ban only applies to two sparsely populated regions within the archipelago. Overall it appears that current fishing regulations are inadequate for addressing the direct threat to island grouper from fisheries overutilization. Current regulations are also likely inadequate to control overfishing of the main sea urchin predators which, based on recent studies from the Canary islands, has resulted in a trophic cascade that has modified and degraded island grouper habitat.

In recent decades, no-take MPAs have received increased attention as a conservation tool aimed at protecting vulnerable fish populations (Halpern and Warner, 2002). The effectiveness of no-take reserves depends, to a large extent, on the relative amount of time individual fish spend protected within reserve boundaries versus outside the reserve where they are susceptible to fishing (Afonso et al., 2011). This will, in turn, be a function of the size and stability of the individual's home range or activity area across time (Kramer and Chapman, 1999). No-take reserves should be particularly effective at protecting stocks of benthic, site attached species with low dispersal and spatially limited home ranges throughout their lives (Kramer and Chapman, 1999; Halpern and Warner, 2003). Afonso et al. (2011) studied site attachment of dusky grouper within the Monte da Guia Marine Reserve (Azores) using passive acoustic telemetry. Results showed that 7 out of 11 tagged groupers never left the 282 ha marine reserve during the entire 5-year study period (2005-2009), and individuals maintained quite small core home ranges that were very stable in the long term. Although site attachment and home range size have not been studied in island grouper, this study suggests that relatively small no-take marine reserves can promote the long-term recovery of vulnerable grouper species that display strong site fidelity. Increased fish density and size within no-take reserves may also increase reproductive potential by promoting the occurrence of spawning aggregations (Sanchez-Lizaso et al., 2000). However, effective protection of grouper species that form spawning aggregations will likely require no-take reserves that include aggregation sites or seasonal fishery closures during reproductive periods (Gruss et al., 2014).

Most studies of MPA effectiveness in the Macaronesian islands have shown higher biomass within MPA boundaries compared to unprotected areas, particularly for large-bodied, vulnerable target species (García-Charton et al., 2008). The "reserve effect" on island grouper abundance (i.e., higher abundance within than outside reserve boundary) was reported for one reserve on Madeira island and two reserves in the Canary Islands archipelago. However, overall the system of MPAs throughout the Macaronesian archipelagos is likely inadequate to protect island grouper from the threat of fishing overutilization. No-take zones account for only a small fraction of the total area covered by MPAs within the island grouper's range, as most areas still allow some types of fishing. In the Azores, Madeira and Canary Islands, there are only five no-take marine reserves, which occupy a total area of 28 km² (Fenberg et al., 2012). Given their small size and physical isolation from one another, no-take zones may lack the connectivity to allow the flow of larval and juvenile fish across islands and archipelagos within the region (Martín-García et al., 2015). There are also no MPAs or time-area closures designed specifically to protect island grouper during spawning periods, and little is known about the timing, location, or frequency of spawning aggregations in this species.

Analysis of Overall Extinction Risk

Island grouper overall extinction risk was determined based on my qualitative assessment of the specific demographic viability risk factors and ESA Section 4(a)(1) threats (discussed in more detail above), and the interplay among those factors and threats. Due to the lack of information regarding threats and the species' life history and ecology, significant uncertainties exist surrounding the levels of risk posed by these demographic factors and threats. Scientific and commercial information available for this analysis was limited, both temporally and spatially. The general lack of time series abundance information and basic fisheries data for island grouper, and sparseness or complete absence of any information from large portions of the species' range, contribute to the uncertainty associated with this assessment.

Data from UVC sampling and fisheries landings indicate that the island grouper is rare throughout much of its limited range and very rare in some areas subjected to heavy fishing pressure. Of the 85 grouper species assessed by Morris et al. (2000), the island grouper was one out of only four species characterized as having both a "restricted" overall range and a "narrow" depth range. Although there are no population abundance estimates available for island grouper, low and decreased density combined with a highly restricted range indicate that small population size is likely a risk factor for this species. Demographic viability factors related to growth rate and productivity are also likely to contribute to the extinction risk based on the following island grouper life history characteristics: slow growth, late maturation, low population turnover rate, large size, and long life span (Bustos, 2008). While slow growth after the first few years is typical for species of *Mycteroperca*, the island grouper is one of the slowest growing species within this genus (Bustos et al., 2009). Although information on spatial structure, connectivity, and dispersal characteristics specific to island grouper is sparse, it is somewhat likely that these factors represent a demographic viability risk to this species. Typical of archipelago ecosystems, the Macaronesian islands are highly fragmented, as geographic distances, bathymetry, and other physical factors result in various degrees of isolation between islands and local populations of demersal fish species (Medina et al., 2007). Island grouper are rare in many areas studied, and the few documented areas with relatively higher abundance are small and patchily distributed throughout the species' range. The available information suggests that this species is inherently susceptible to fragmentation which could result from further population declines. Because there is insufficient information on genetic diversity, this demographic viability criterion presents an unknown likelihood of contributing to the island grouper's extinction risk.

The island grouper's intrinsic vulnerability to fishing is very high (Saavedra, 2011; Diogo and Pereira, 2013a). Demographic viability risk factors related to the island grouper's growth rate, productivity, spatial structure, and range size all contribute to this species' vulnerability to fishing overexploitation (Bustos, 2008; Bustos et al., 2009; Saavedra, 2011; Diogo and Pereira, 2013a). As a protogynous hermaphrodite, the island grouper may be even more susceptible to fishing which, through selective removal of males, could reduce reproductive capacity (Huntsman and Schaaf, 1994; Bustos et al., 2010). Certain behavioral traits (i.e., territoriality, site specificity, and spawning aggregations), which are common among groupers, often result in grouper species being an easy target for fishermen (Randall and Heemstra, 1991; Domeier and Colin 1997). Although not well-studied in the island grouper, these traits may also add to the fishing vulnerability of this species. The economic value of the island grouper is also a factor

that likely contributes to overutilization of this species. Groupers are highly prized by commercial and artisanal fishermen for the quality of their flesh, and most species (including island grouper) fetch high market prices (Heemstra and Randall, 1993; Ribeiro, 2008).

Historical fisheries data are not available to evaluate long-term trends in island grouper landings, directed effort, or catch rates over time. The limited commercial and artisanal catch data available indicate that, in recent years, island grouper landings have been relatively small, and this species is currently a very minor component of commercial and artisanal fisheries throughout its range. The small contribution to recent fisheries landings is consistent with abundance information suggesting the island grouper is generally a rare species. Although fishing intensity is highly variable between islands, there are indications that artisanal fishing pressure for demersal species, in general, is relatively high in many areas throughout the island groupers' range. The depleted status of commercially important stocks of tunas and small pelagics in the Macaronesian region has also likely contributed to the increased fishing pressure on coastal demersal species in recent years (Moreno-Herrero, 2011; DeAlteris, 2012).

Several studies have shown a negative correlation between island grouper abundance and level of fishing pressure (Tuya et al 2006a; Bustos, 2008; Ribeiro, 2008; Sangil et al., 2013a; Sangil et al., 2013b). These results suggest that fisheries overexploitation has negatively impacted island grouper abundance, and some heavily fished areas in the Canary Islands have likely experienced a sharp decline. This is particularly concerning for a rare species, with a limited range, and high intrinsic vulnerability to the effects of overfishing due to certain life history and behavioral traits. The lack of baseline abundance information and a time series of fishery dependent data, combined with limitations of the available studies, make it difficult to quantitatively assess the impact of this threat on island grouper abundance or species' survival. However, based on the cumulative information available, I conclude that there is a reasonable likelihood that artisanal fishing overutilization contributes to the island grouper's risk of extinction in a significant way (i.e., in a sufficiently great or important way as to be worthy of attention). There are also indications that rapidly expanding recreational fisheries contribute significantly to the overutilization of island grouper in some parts of the species' range.

Current fishing regulations designed to limit catch and effort are inadequate for addressing the direct threat to island grouper from fishing overutilization. In general, there are few restrictions placed on demersal fisheries throughout the island grouper's range. In areas where regulations (e.g., size limits and gear restrictions) do exist, their effectiveness is likely reduced by lack of enforcement and relatively high levels of non-compliance.

A well-designed system of no-take MPAs may be better suited than traditional fishing regulations for addressing the threat of fishing to highly vulnerable, nearshore demersal species. The "reserve effect" on island grouper abundance (i.e., higher abundance within than outside the reserve boundary) was reported for one reserve on Madeira island and two reserves in the Canary Islands archipelago. However, no-take zones account for only a small fraction of the total area covered by MPAs within the island grouper's range, as most MPAs still allow some types of fishing. Given their small size, physical isolation from one another, and insufficient enforcement, the currently established no-take zones are likely inadequate to protect island grouper from the future threat of fishing overutilization. Overall, I conclude that there is a

reasonable likelihood that the lack of adequate regulatory mechanisms and enforcement represent threats to the island grouper that contribute significantly to this species' extinction risk.

Due to the species' preferred depth range, and the surrounding volcanic island bathymetry, island grouper habitat is typically confined to a narrow band within a few kilometers from shore. Close proximity to the shore increases the risk of habitat modification from human activities within the coastal zone, particularly on the more densely populated Macaronesian islands. Potential threats to island grouper habitat include: declines in benthic cover (i.e., seaweeds and macroalgae) due to overfishing of key sea urchin predators; physical alteration and armoring of the coast; destructive fishing practices; pollution; and the effects of global climate change (see section "Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range" for more details). While these ecosystem disturbances are well documented, studies linking habitat related threats to declines in island grouper abundance are lacking. Although the cumulative impact of anthropogenic threats has likely modified some portion of the island grouper's habitat, there is not enough scientific information available to support a conclusion that habitat associated changes contribute to the extinction risk of this species in a significant way. The introduction of invasive species from aquaculture escape events and ship ballast water also poses a potential threat to island grouper through increased competition for limited resources (e.g., food, shelter) and the possible spread of diseases and parasites. However, as with habitat related threats, there is not enough scientific information available to support a conclusion that threats related to competition, disease or predation contribute to the island grouper's extinction risk in a significant way.

In summary, the island grouper exhibits demographic risk factors related to abundance, growth rate and productivity, and spatial structure and connectivity. The cumulative magnitude of these risk factors is likely approaching a level of vulnerability that places the species' persistence in question. In addition, there is a reasonable likelihood that the operative threats of fishing overutilization and the lack of adequate regulatory mechanisms contribute significantly to the island grouper's risk of extinction. After considering the cumulative evidence from all the information available, **I conclude that the island grouper faces a moderate risk of extinction throughout its range.**

Conservation Efforts

As part of the European Union, the Azores, Madeira, and Canary Islands archipelagos participate in and are influenced by EU conservation initiatives. In 2008 the EU adopted the Marine Strategy Framework Directive⁵ (MSFD) in order to achieve Good Environmental Status (GES) through ecosystem-based management in EU waters by 2020. To comply with the MSFD, member states must ensure that their biological and physical marine features adhere to the specific qualitative descriptors of GES for the maintenance of biological diversity, habitat quality, and sustainable harvest levels of fish and shellfish stocks (Fenberg et al., 2012). The establishment of a coherent network of marine protected areas (MPAs) is the only mandated measure of the MSFD. The emphasis on marine protected areas and biodiversity in the MSFD

⁵ Source - http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm

reinforces previously established commitments in the European Biodiversity Strategy and obligations under the international Convention on Biological Diversity (Bellas, 2014). The Portuguese government approved two MSFD strategies in 2012, one for the continental EEZ and one for the extended continental shelf, but no MSFD strategy has yet been approved by the autonomous governments of the Azores and Madeira archipelagos (Santos et al., 2014). In Spain, the MSFD has resulted in passage of the 2010 Law on the Protection of the Marine Environment (LPME). The LPME provides a general legal framework for the conservation and sustainable use of marine resources, as well as specific language regarding the creation and management of a Spanish network of MPAs (Bellás, 2014). To facilitate regional implementation of marine strategies, the LPME establishes five subdivisions (or “marine demarcations”), one of which is the Canary Islands demarcation. The adoption of the MSFD policy demonstrates a general willingness to achieve long-term protection of Europe’s marine ecosystems, but whether the political will is strong enough in the Macaronesian Islands to achieve its objectives remains to be seen (Santos et al., 2014).

Four proposed Canary Islands MPAs are currently waiting to be approved by the Spanish government; one on the north coast of La Gomera, two in Tenerife (Teno and Anaga) and one on the east coast of Gran Canaria (Riera et al., 2014). The creation of a network of marine reserves is considered a priority for the conservation of Canarian marine coastal ecosystems into the future. However, previous attempts to establish new MPAs in the Canary Islands have often been stalled or abandoned due to stakeholder opposition, political infeasibility, and lack of funding (Chuenpagdee et al., 2013). For example, the regional island government of Tenerife has been promoting the creation of MPAs on Tenerife since 2004. Two proposed MPAs were finally approved in 2010 - six years after initial planning started – but to date neither one has been implemented. According to Chuenpagdee et al. (2013), there is no guarantee that these MPAs ever will be implemented, “given the lack of fluidity of the process, the often hidden way that power works, the economic crisis in Spain, and the unpredictability of politics.”

A joint United Nations Development Program (UNDP) and Global Environmental Facility (GEF) project titled “Consolidation of Cape Verde’s Protected Areas System” was initiated in 2010 in an effort to strengthen and expand Cape Verde’s national system of terrestrial and marine protected areas (UNDP, 2013). Project objectives include: 1) consolidation, expansion, and operationalization of existing MPAs on the islands of Sal and Boavista for the protection of fisheries resources, 2) building the national capacity for MPA management through new management sectors and authorities, and 3) promotion of participatory approaches in the management and conservation of the endemic biodiversity of Cape Verde. The project is expected to add 41,214 ha of terrestrial and marine protected areas (i.e. a 38% expansion over the baseline).

Other regional, local and grassroots efforts are underway to conserve and protect marine resources in the Macaronesian Islands. Local nongovernmental organizations (NGOs) and regional governments in the Canary Islands are promoting the creation of Micro Areas Ecosturísticas Litorales (MAELs). Due to their small scale, MAELs are less demanding on public funding, typically less contentious, and follow a different legal model compared to larger scale MPAs (Riera et al., 2014). A well-designed and enforced network of MAELs could provide additional conservation benefit to demersal fish populations in the Canary Islands. The Canarias

por una Costa Viva program⁶ is a partnership among NGOs, universities, and local and regional governments. Costa Viva program objectives include studying the impacts of human population pressures on the coastal environment, increasing marine environmental education and awareness, promoting and facilitating stakeholder involvement in marine resource management, and collaborating with government agencies in the sustainable use of Canary Islands marine resources. The Azores University SMARTPARKS program (Planning and Management System for Small Islands Protected Areas) is aimed at facilitating the development of sustainable protected areas in the Azores through active involvement of stakeholders, promotion of economic and cultural activities compatible with nature conservation, and innovative planning and management of protected areas at the island scale (Fonseca et al., 2014).

The island grouper is listed as “vulnerable” under the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Nieto et al., 2015).

⁶ Source - <http://www.canariasporunacostaviva.org/index.html>

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